State of Louisiana

Coastal Protection and Restoration Authority of Louisiana (CPRA)

2020 Operations, Maintenance, and Monitoring Report

for

Sabine Structure Replacement

State Project Number CS-23
Priority Project List 3

December 2020
Cameron Parish

Prepared by:
Mike Miller, Mark Mouledous
Dion Broussard, P.E.
and
Jody White, P.E.

CPRA – Operations Division
Lafayette Regional Office
635 Cajundome Blvd.
Lafayette, LA 70596

Suggested Citation:

Mouledous, M., M. Miller., Broussard, D. and White, J. 2020. *2020 Operations, Maintenance, and Monitoring Report for Sabine Structure Replacement (CS-23), Louisiana Coastal Protection and Restoration Authority of Louisiana, Office of Coastal Protection and Restoration, Lafayette, Louisiana*. 32 pp plus appendices.

2020 Operations, Maintenance, and Monitoring Report
For
Sabine Structure Replacement (CS-23)

Table of Contents

Preface

This report includes monitoring data collected through December 2019, and annual Maintenance Inspections through May 2020.

The 2020 report is the 7th and final report in this series of reports. For additional information on lessons learned, recommendations and project effectiveness please refer to the 2004, 2005, 2007, 2010 2013 and 2016 Operations, Maintenance, and Monitoring Reports on the LDNR web site (http://sonris-www.dnr.state.la.us/sundown/cart_prod/cart_bms_avail_documents_f).

I. Introduction

The Replace Hog Island Gully, West Cove and Headquarters Canal Structures (CS-23) project area is located within the Sabine National Wildlife Refuge, approximately 9 mi (14.5 km) south of the town of Hackberry in Cameron Parish, Louisiana (Figure 1). Established on December 6, 1937, the Sabine Refuge is bound on the east by Calcasieu Lake, on the west by Sabine Lake, on the north by broken marsh, and on the south by pasture land and coastal ridges.

The project area was characterized as fresh to intermediate marshes dominated by *Cladium mariscus* (Jamaica sawgrass) (O'Neil 1949). The Black Lake area, located north of the project, experienced an 81% reduction in the acreage of emergent wetlands between 1952 and 1974 (Adams et al. 1978). By 1972, the Black Lake area was characterized as brackish marsh (Chabreck and Linscombe 1978). A number of factors such as salinity stress, erosion, subsidence, burning and hydrologic modification influenced this habitat change.

Water management by weirs was initiated in the 1970's to control flows through Hog Island Gully, West Cove Canal, and Headquarters Canal. By the 1990's, these structures had corroded with the continuous exposure to saline water to the extent that they were inoperable or almost inoperable.

Due to the detrimental impacts of excess salinity on brackish and intermediate marshes, the ability to occasionally reduce or halt the inflow of saline water is critical. This level of control was not available with the original structures. The inability to manipulate gate structures jeopardized the integrity of thousands of acres of interior brackish and intermediate marshes.

Because of the restricted cross-sectional area of the pre-existing structures and culverts, the lower elevation interior marshes experienced longer periods of vegetative water logging stress than the marshes located east of Highway 27. The pre-existing structures afforded the primary avenues for drainage and were inadequate to provide sufficient discharge to evacuate excess water. Due to the project area not being fully enclosed, secondary drainage for the area could occur to the west through Sabine Lake via North, Central and South line canals.

In May 1999, the US Fish and Wildlife Service (USFWS) completed the environmental assessment (EA) plan addressing the Replacement of Water Control Structures at Hog Island Gully, West Cove Canal, and Headquarters Canal (CS-23) (USFWS 1999). The plan called for the complete

removal of the Hog Island Gully Structure, West Cove Canal Structure, and Headquarters Canal Structure and replacement with additional structures and culverts to provide larger cross sections for water removal and to minimize saltwater intrusion.

The replacement structures should be operated to more effectively discharge excess water, increase cross sectional area for ingress and egress of estuarine dependent species and more effectively curtail saltwater intrusion into the interior marshes.

Construction began in November 1999 and was completed on the Hog Island Gully, West Cove, and Headquarters Canal structures in August 2000, June 2001, and February 2000, respectively. There were however operational issues after construction at the Hog Island Gully and West Cove structures due to electrical service problems and operating nut failures which prevented the structures from being operated as designed. Hurricanes Rita (2005) and Ike (2008) exacerbated the damage to the structures. After various post-construction maintenance events and an extensive refurbishment, which included electrical component replacement and slide gate conversion from one to two stems, in April 2011, the Hog Island Gully and West Cove structures have been repaired and are fully operational. Routine openings by the USFWS began in December 2011.

Currently, high saline waters can be controlled, water discharge capacities have been increased and vegetative stress through water logging can be minimized which should enhance emergent and submerged vegetative growth.

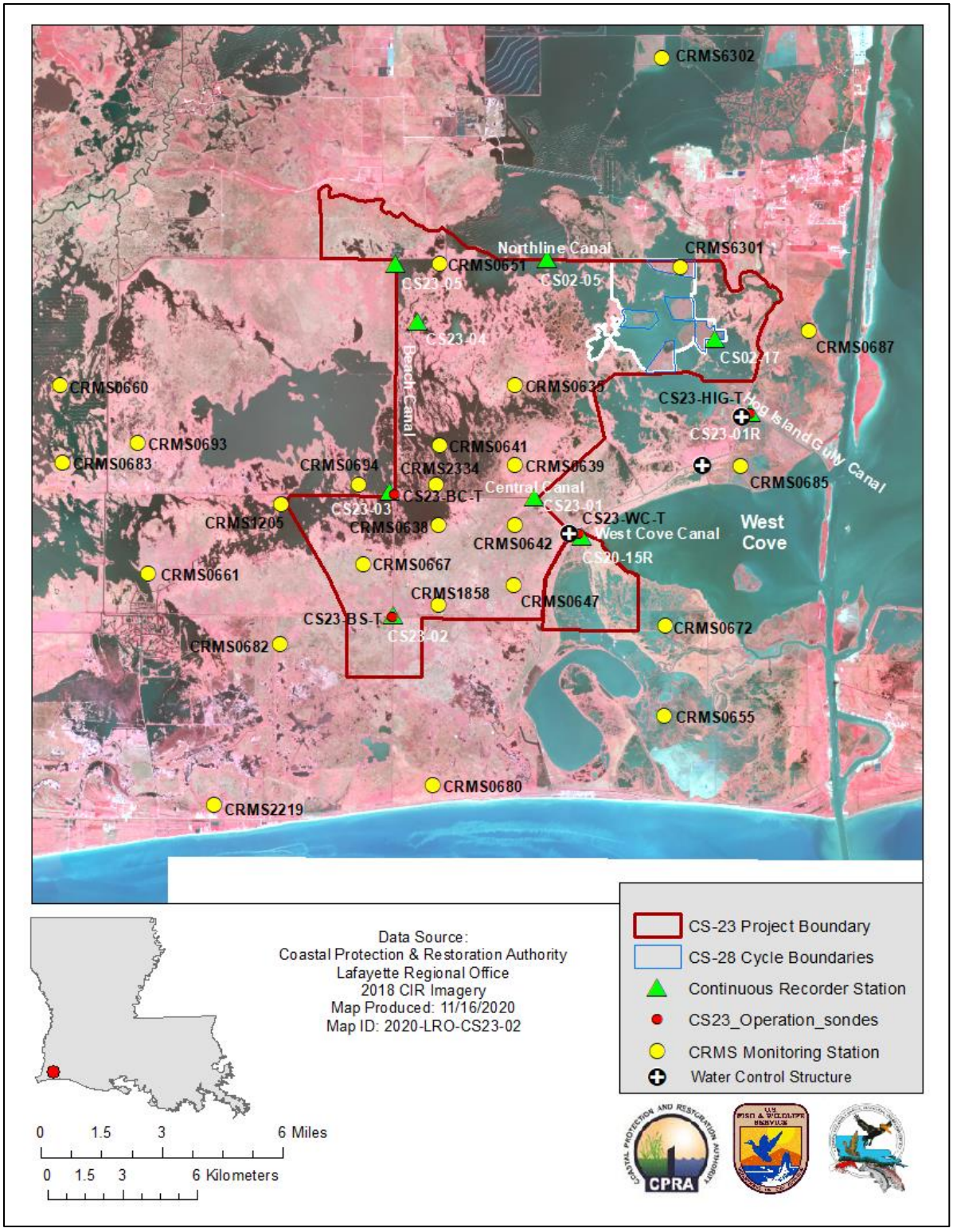


Figure 1. Replace Hog Island Gully, West Cove and Headquarters Canal Replacement Structures (CS-23) project features, CRMS Sites, project area boundaries and reference area boundaries.

II. Maintenance Activity

a. Project Feature Inspection Procedures

The purpose of the annual inspection of the Sabine Refuge Structure Replacement Project (CS-23) is to evaluate the constructed project features to identify any deficiencies and prepare a report detailing the condition of project features and recommended corrective actions needed. Should it be determined that corrective actions are needed, CPRA shall provide, in the report, a detailed cost estimate for engineering, design, supervision, inspection, and construction contingencies, and an assessment of the urgency of such repairs (O&M Plan, 2002). The annual inspection report also contains a summary of maintenance activities which were completed since project completion and an estimated projected budget for the upcoming three (3) years for operation, maintenance and rehabilitation. The three (3) year projected operation and maintenance budget is shown in Appendix B. A summary of past operation and maintenance projects completed since completion of the Sabine Refuge Protection Project are outlined in Section IV.

An inspection of the Sabine Refuge Structure Replacement Project (CS-23) was last held following hurricanes Laura and Delta. The post Laura inspection was performed on September 09, 2020, while the post Delta inspection was performed on October 22, 2020.

The field inspection included an inspection of all three project sites. Staff gauge readings and existing temporary benchmarks where available were used to determine approximate elevations of water, rock embankments, concrete structures and other project features. Photographs were taken (see Appendix A) and Field Inspection notes were completed in the field to record measurements and deficiencies (see Appendix C).

b. Inspection Results

Structure A - Hog Island Gully Canal

Storm surge from Hurricane Laura scoured around the ends of the structure. Damage can be repaired with placement of soil and rip rap. A boat barrier cable and buoy have detached from the timber pole danger sign. (Photos: Appendix A, Photos 1 - 2)

Structure B - Headquarters' Canal

The refuge headquarters facility is closed and the gates were locked. Therefore, close assessment was not able to be made. Observing the structure from across the canal, it appeared that the structure did not receive any damage. (Photos: Appendix A, Photos 3).

Structure C - West Cove Canal

Storm surge from Hurricane Laura scoured around the ends of the structure. Damage can be repaired with placement of soil and rip rap. There was also damage to the various fishing piers (not maintained by CWPPRA). (Photos: Appendix A, Photos 4 - 5).

c. Maintenance Recommendations

i. Immediate/ Emergency Repairs
No repairs are required at this time.

ii. Programmatic/ Routine Repairs
A maintenance event to perform targeted canal cleanout in the project area was proposed and approved in the Fall of 2020. The storm related damage can be folded into this larger maintenance event. This work should be completed by the end of 2021 or early 2022.

d. Maintenance History

General Maintenance: Below is a summary of completed maintenance projects and operation tasks performed since June 2001, the construction completion date of Sabine Refuge Structure Replacement Project (CS-23).

- **June, 2005 – F. Miller & Sons, Inc.**
  A maintenance event was performed to correct the following:

  1. Install operating nut in gate 6A, Hog Island Gully.
  2. Free gate 6b that is jammed, Hog Island Gully.
  3. Replace operation nut in gate 3A, West Cove.
  4. Replace batteries in all Rotork Actuators and re-calibrate.

  Construction (Item Nos. 1, 2 & 3): $ 7,800.00
  Construction (Item No. 4): $ 5,416.45

  PROJECT TOTAL: $13,216.45

- **June, 2006 – U.S. Fence & Gate, Inc.**
  A maintenance event was performed to correct the following:

  Remove existing fence and posts damaged by Hurricane RITA at both Hog Island Gully and West Cove Structures and replace with new chain link fence material and new posts.

  Construction Cost: $8,360.00
  Engineering Design and Construction Oversight: In-House

  PROJECT TOTAL: $8,360.00

- **June – October, 2008** – **Electrical Repairs by USFWS via Tennessee Valley Authority (TVA)**

  The TVA, under contract with USFWS and post-Rita funds, replaced storm-damaged wiring, installed true 3-Phase power from Jeff Davis Electric Co-Op transformers at Highway 27 to the structures, relocated all controls to the top platform, removed the rotary phase converter, and wired the actuators using an on-off control switch.

  PROJECT TOTAL: $232,979

- **2009 - Lonnie Harper & Associates - E&D of Repairs and Modifications to Structures**

  Post-Rita FEMA funding was used for preparation of plans and specifications for structure repair and modifications.

  FEMA ALLOWANCE: $144, 185

- **September, 2009 – A-1 American Fence, Inc.**

  A maintenance event was performed to correct the following:

  Remove existing fence and posts damaged by Hurricane Ike at both Hog Island Gully and West Cove Structures and replace with new chain link fence material and new posts.

  Construction Cost: $ 5,500.00
  Engineering Design and Construction Oversight: $18,566.93

  PROJECT TOTAL: $24,066.93

- **April, 2011 – L.S. Womack, Inc.**

  A maintenance event was performed to correct the following:

  1. Dismantling of Hog Island Gully and West Cove structures.
  2. Cleaning and performing modifications to all gates at both Hog Island Gully and West Cove structures.
  3. Refurbishing gear drives and actuators for gates where 3” stems were to be replaced with 2.5” stems.
  4. Refurbishing the gear drive and actuator at Headquarters.

5. Structural modifications to the 7'-6" gates at both Hog Island Gully and West Cove structures included modifying the stem attachments to accommodate a dual stem configuration.
6. Removal of the leak proof gasket, modify structural steel platforms at Hog Island Gully and West Cove structures to accompany new gate connection and stems.
7. Reworking of all electrical connections to provide complete operation of all three structures.
8. During construction, it was determined that the gates required structural repairs to maintain the integrity of the gates. 193 stitch welds were performed on 22 gates, to repair broken welds and strengthen the integrity of the gates.

Construction Cost:	$1,288,934.82
Engineering Design and Construction Oversight:	$ 64,077.11
PROJECT TOTAL:	**$1,353,011.93**

III. Operation Activity

a. Operation Plan

Normal Operation: The structures are operated based on salinity and water level data. The targeted levels are defined in the permitted Operational Plan (See Appendix E). Water exchange will be provided through open bays having approximately the same cross-sectional area as that provided by the old structures' fully open gates [182 ft^2 total area]. The slide/sluice gates of the flapgated bays may be adjusted by the refuge manager at his discretions, except for the middle Headquarters' Canal Structure culvert (HQ2) which will remain 50 percent open. All flapgates will remain down in the operating position, except for HQ2 in which the flapgate will be locked closed to serve as the sluice gate.

Hog Island Gully Canal-Structure A: Normal management of this structure would provide a cross-sectional area of 112 ft^2 compared with 93.5 ft^2 of gated opening in the old structure.

HG1	HG1	HG2	HG2	HG3	HG3	HG4	HG4	HG5	HG5	HG6	HG6
Slide Gates	Flap Gate	Slide Gates	Flap Gate	Slide Gates	Flap Gate	Slide Gates	Flap Gate	Slide Gates	Flap Gate	Slide Gates	Flap Gate
MD	Down	MD	Down	-7'	None	-7'	None	-7'	None	MD	Down

MD=Manger's discretion

Headquarters' Canal – Structure B. Normal management provides a cross-sectional area of approximately 10 ft^2 compared with 0 to 12.6 ft^2 of gated opening maintained through operation of the old structure.

HQ1 Sluice	HQ2 Sluice	HQ3 Sluice
Sluice Open	Sluice ½ Open	Sluice Open

West Cove Canal - Structure C. Normal management would provide a cross-sectional area of 60 ft^2 compared to 59.5 ft^2 of gated opening in the old structure.

WC1 Slide Gage	WC1 Flap Gate	WC2 Slide Gate	WC2 Flap Gate	WC3 Slide Gate	WC3 Flap Gate	WC4 Slide Gate	WC4 Flap Gate	WC5 Slide Gate	WC5 Flap Gate
MD	Down	+2'	None	-7'	None	+2'	None	MD	Down

Deviations from normal operation will be short-term and conducted for the reason identified below.

Increased Exchange Operation:

Additional gates may be temporarily opened to the degree necessary as determined by the refuge manager for any of the following reasons.

1) To discharge excess water
2) To facilitate inflow of freshwater, or water of lower salinity
3) To enhance ingress and egress of estuarine-dependent fishes and shellfishes
4) To discharge anoxic waters

High Water Provisions: When water levels in interior marshes exceed four inches above average marsh level for four days or more, the discharge capacity of structures A, B, and or C will be increased with flap gates or by raising slide gates or sluice gates to permit outflows. Normal operation will be restored when the water conditions have receded.

Storm provisions: Prior to a storm's approach, flapgated bays may be readied in advance for later discharge of excess water by raising and thereby opening the sluice gates of those bays equipped with flapgates. Prior to a storm's approach, refuge personnel may restrict or close non-flapgated bays to reduce exposure or interior marshes to saltwater tidal surges. Following a storm, normal or restricted water exchange operations shall be resumed on non-flapgated bays in accordance with the established salinity and water level provisions and criteria. In an attempt to reduce the exposure of interior marshes to saltwater because of tropical depression tidal surges, the gates will be closed precluding any surges. Following the inundation of high tides and rainfall, the gates will be opened to alleviate interior marsh flooding.

Monitoring Activities: Baseline salinity and water level monitoring, using continuous recorders, began in April 1998 using the standard Coastal Wetlands, Planning, Protection, and Restoration Act monitoring protocol (Steyer et. al 1995, revised 2000). The Coastal Protection and Restoration Authority (CPRA) have deployed six continuous monitoring recorders (sondes) within the project area. The U.S. Fish and Wildlife Service (USFWS) collected salinity, water temperature and specific conductivity parameters at area stations approximately every two weeks until structure operations began after 2001. Due to the impending installation of Coastwide Reference Monitoring System (CRMS) stations (Figure 1), data collection at two of the continuous recorder monitoring stations (CS23-01 and CS23-02) was discontinued in May 2004. The remaining continuous recorder monitoring stations (CS23-BS-T, CS23-BC-T, CS23-HIG-T, and CS23-WC-T are setup with telemetry capabilities and will be used for data collection and to aid in structure operations (Figure 1).

b. Actual Operations

In accordance with the operation schedule outlined in the Operation and Maintenance Plan and USACE Permit, structures are operated by USFWS personnel. However, the Hog Island Gully and West Cove structures were not fully operational until December 2011 due to electrical service issues, operating nut failures, Hurricanes Rita 2005 and Ike 2008. Copies of the actual operation reports may be obtained from the USFWS, Sabine National Wildlife Refuge Office located at 3000 Holly Beach Hwy, Hackberry, LA 70645; (*337-762-3816* or *sabine@fws.gov*).

Due to USFWS manpower deficiencies, retirements, and difficulty backfilling positions, an operations contract is being developed to facilitate in the operation of the structures through the end of the project life. The operations contract will be facilitated by the CPRA (Lafayette Regional Office) and operations will be approved by USFWS personnel.

IV. Monitoring Activity

a. Monitoring Goals:

The objective of the Hog Island Gully, West Cove & Headquarters Canal Structure Replacement Project is to increase the cross-sectional area and operation ability of the projects water control structure features to improve hydrologic conditions that control high saline waters, increase water discharge capacities, and maintain emergent vegetation.

The following goals will contribute to the evaluation of the above objectives:

1. Reduce the occurrence of salinities that exceed target levels during the growing and non-growing seasons at stations CS23-02, CS23-03, CS23-05 and CS02-05. Target levels range from 2 – 8 ppt during the growing season and 3 – 10 ppt during the non-growing season.

2. Minimize frequency and duration of marsh flooding events.

3. Maintain existing intermediate and brackish vegetation communities.

4. Increase occurrence of submerged aquatic vegetation (SAV).

b. Monitoring Elements

Aerial Photography

To document land and water acreage and land loss rates in project and reference area, near-vertical color infrared aerial photography (1:12,000 scale) was obtained pre-construction in 2000. The original photography was checked for flight accuracy, color correctness, and clarity and was subsequently archived. Aerial photography was scanned, mosaicked, and georectified by USGS/NWRC personnel according to standard operating procedures (Steyer et al. 1995, revised 2000). Based on the CRMS review, aerial photography originally scheduled for 2004, 2009 and 2018 was eliminated. Project scale land trends were calculated using Landsat Thematic Mapper (TM) data for 1984 – 2016. Linear regressions were calculated for the period of record. The variability in percent land data points around the slope illustrate the influence of various sources of environmental variance or classification error. Positive slopes indicate increasing percent land or historical land gain and negative slopes indicate decreasing percent land or historical land loss (Couvillion et al., 2017). The data provided by this tool is at a large spatial scale and is designed to show trends in land change, not exact acreages.

Salinity

CRMS data from 19 sites, eleven inside the project area (CRMS0635, 638, 639, 641, 642, 647, 651, 677, 1205, 1858, and 2334), two on the perimeter of Calcasieu Lake (CRMS0685, 687), and six in the interior marsh west of the project (CRMS0660, 661 682, 683, 693, and 694) were utilized to assess salinity goals (Figure 1). The sites chosen were all open-water sonde setups, and not

marsh well setups. Salinity was monitored hourly from 1/1/2008 -12/31/2019 (post-construction) and will be used to identify the amount of time that salinities exceed target levels within the project area.

Water Level

CRMS data from 19 sites, eleven inside the project area (CRMS0635, 638, 639, 641, 642, 647, 651, 677, 1205, 1858, and 2334), two on the perimeter of Calcasieu Lake (CRMS0685, 687), and six in the interior marsh west of the project (CRMS0660, 661 682, 683, 693, and 694) were utilized to assess water variability goals (Figure 1). The sites chosen were all open-water sonde setups, and not marsh well setups. Water level was monitored hourly from 1/1/2008 - 12/31/2019 (post-construction) and will be used to identify annual duration and frequency of flooding. A staff gauge has been surveyed adjacent to each CRMS site to correlate water levels to a known datum. Marsh elevations are correlated to the staff gauges and will be used in determining marsh flooding events.

Vegetation

CRMS data from 19 sites, eleven inside the project area (CRMS0635, 638, 639, 641, 642, 647, 651, 677, 1205, 1858, and 2334), two on the perimeter of Calcasieu Lake (CRMS0685, 687), and six in the interior marsh west of the project (CRMS0660, 661 682, 683, 693, and 694) were utilized to assess percent cover and species composition by salinity (Figure 1). In order to assess the project goal of maintaining intermediate and brackish vegetation communities, vegetation data was assigned a salinity category based on what marsh type the individual species were most commonly found, e.g. fresh, intermediate, brackish, and saline, along with transitional classes such as fresh-intermediate, intermediate-brackish, and brackish-saline using the Visser classifications (Sasser and Visser 2008). This approach examines marsh type transitions and trends as the process of changing classifications takes place.

Submerged Aquatic Vegetation

To determine the occurrence of SAV within the project and reference area, eight ponds were randomly sampled for presence or absence of SAV using the modified rake method (Nyman and Chabreck 1996). Five ponds are located in the project area and three in the reference area. Transect lines were set up within each pond and a minimum of 25 samples were taken along each transect line, not to exceed 100 samples per line. Depending on pond configuration and wind direction, the number of transect lines within each pond varies. SAV was monitored in 1999 (pre-construction) July 2004, June 2009, June 2014 and October 2018 post-construction.

CRMS Supplemental

In addition to the project specific monitoring elements listed above, a variety of other data is collected at CRMS-*Wetlands* stations which can be used as supporting or contextual information. Data types collected at CRMS sites include hydrologic from continuous recorder and vegetative data which were both used to address monitoring goals of the project (Folse et al. 2020). Other parameters such as physical soil characteristics, discrete porewater, surface elevation, and land: water analysis of 1 km^2 area encompassing the station is given for an environmental overview. For this report, eleven CRMS sites were used to assess hydrologic parameters and vegetation parameters within the project area. Nine CRMS sites outside the project area were used as

reference stations in a traditional project versus reference manner. Data collected from the CRMS network, with a sufficient amount of time to develop valid trends, was used to develop data indices that can be used to indicate project performance.

Soil interstitial (porewater) salinity data were collected monthly from 10 and 30 cm depths at each CRMS site. Monthly porewater salinity data were averaged into yearly means to compare differences within the project and reference areas for years 2006 – 2019. Vegetation plot porewater was excluded from this data set.

Soil cores were collected one time (within a year of site establishment) to describe soil properties (bulk density and percent organic matter). Three, 4" diameter cores were collected to a depth of 24 cm and divided into 6, 4-cm sections at the site. The soil was processed by the Department of Agronomy and Environmental Management at Louisiana State University.

Soil surface elevation change utilizing a combination of sediment elevation tables (RSET) and vertical accretion from feldspar horizon markers are being measured twice per year at each site. This data will be used to describe general components of elevation change and establish accretion and subsidence rates.

c. Monitoring Results and Discussion

Aerial Photography

Land/water analysis was acquired in November 2000, considered pre-construction since the structure were inoperable until 2011 (Figure 2). In this analysis, the project area had a ratio of 67.5% land (28,146.8 ac) to 32.5% water (13,572.1 ac) and the reference area had a ratio of 57.9% (1,695.5 ac) land to 42.1% (1,233.5 ac) water.

The general land trend within the project area prior to construction was positive (151.4 ac/yr) between 1984 -2002 (Figure 3). Incorporating the 2002 to 2016 data, which includes the post-construction satellite imagery, and more importantly, Hurricane Rita in 2005 and Hurricane Ike in 2008, shows a slight loss trend (-14.43 ac/yr). The area lost approximately 5000 acres of land due to the storms. Some recovery has occurred, but the project still has about 2000 fewer acres than it did prior to Hurricane Rita. Note, though, that the CS-28 marsh creation project, which is within the CS-23 project area, added at least 800 acres of land gain. Excluding those acres from the post-construction analysis increases the loss trend within the project to -41.80 ac/yr (Figure 3).

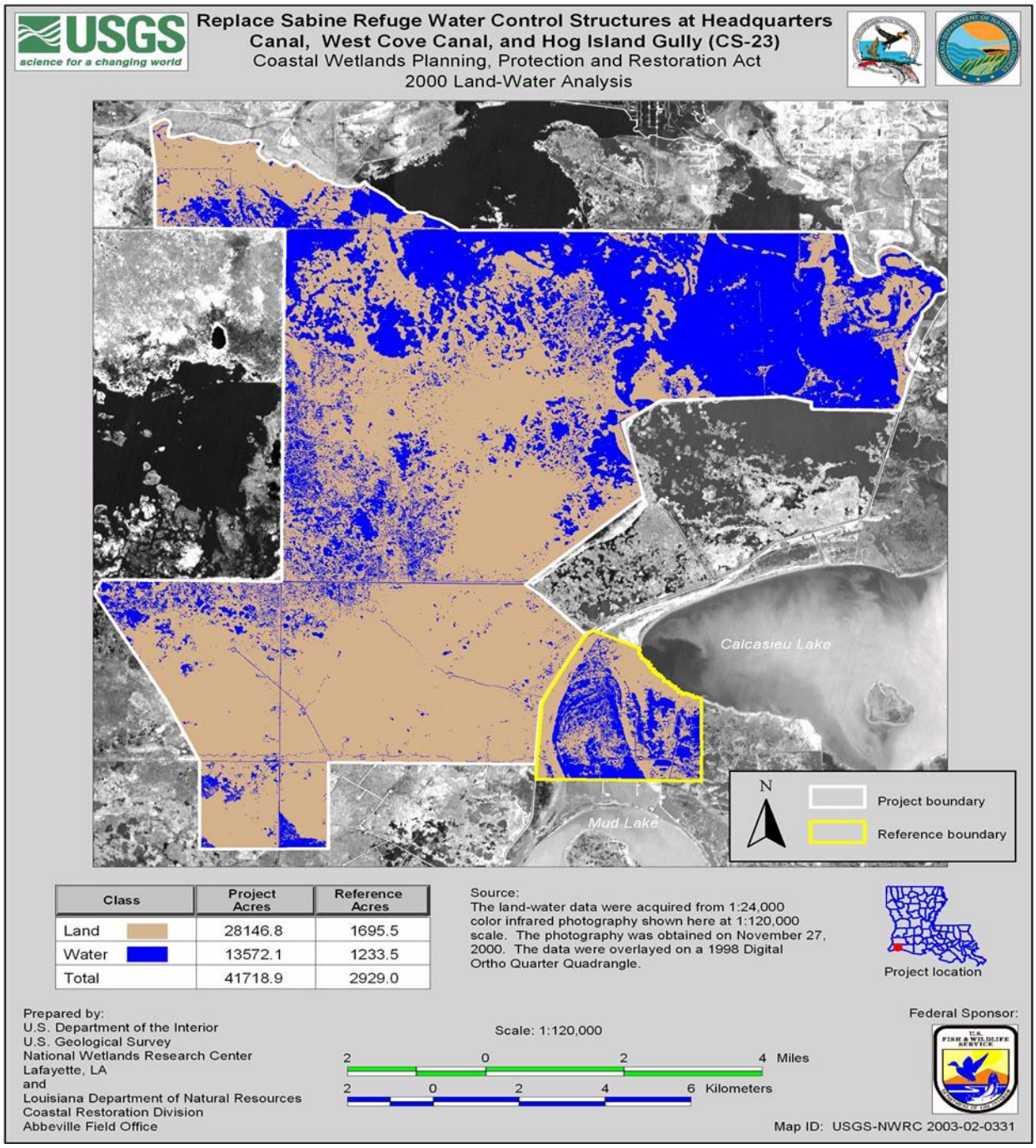


Figure 2. Land/water analysis of the Sabine Structure Replacement (CS-23) for the project and reference areas from photography obtained November 27, 2000.

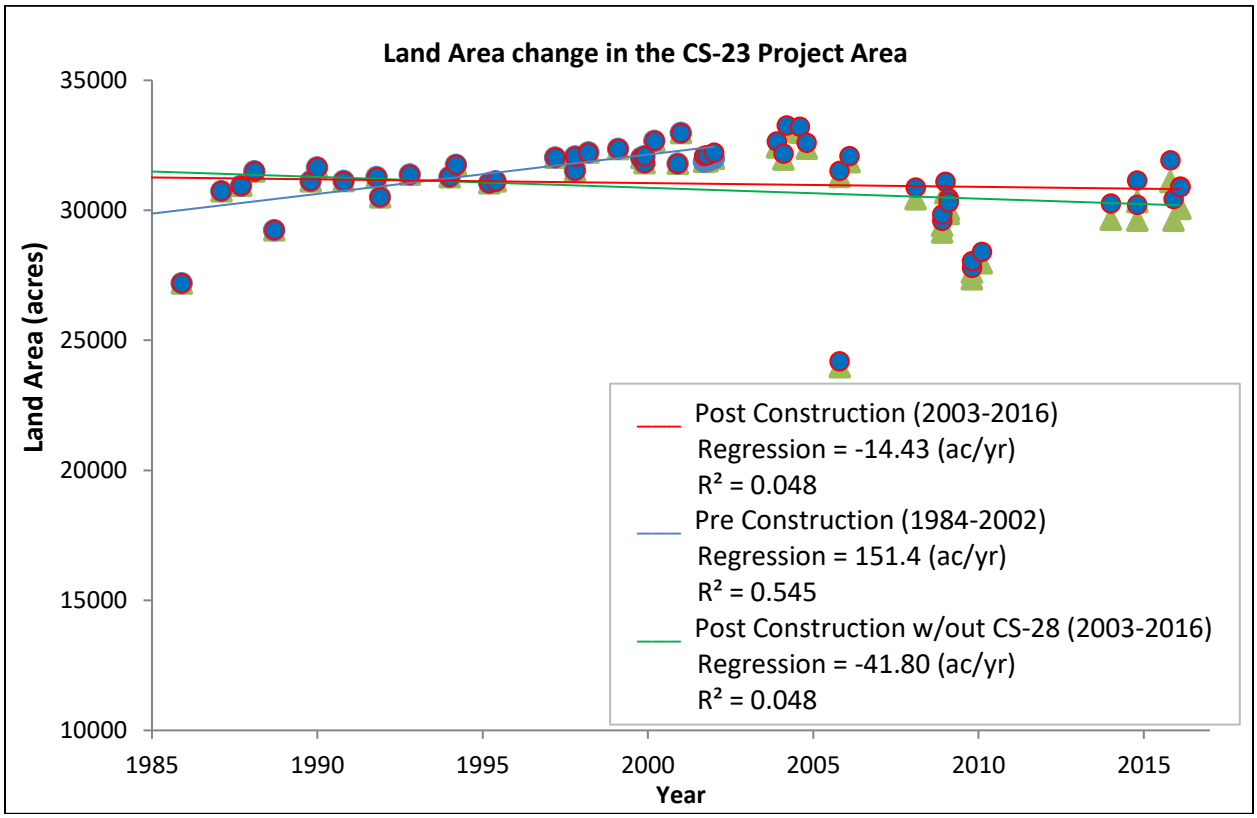


Figure 3. Project scale land area trends, in acres, for the CS-23 project area for years 1985 to 2016. The blue and red lines depict the pre- and post-construction land area, respectively. The green line depicts the post-construction land area with the CS-28 project acreage removed. See Couvillion et al. 2017.

Salinity

Salinity data were collected hourly at nineteen CRMS sites; eleven are CRMS sites located within the CS-23 project area, two are CRMS sites on the perimeter of Calcasieu Lake (Reference Lake), and six are located in the interior marsh west of the CS-23 project area (Reference Marsh). Weekly mean salinity was calculated from the daily means of hourly data from 2008 to 2019 (Figure 4). Prior to the structures being fully functional in 2011, project area salinities are often above target and mimic Reference Lake area salinities. With the ability to fully operate the structures in 2012, the prevention of saltwater into the project area is evident as salinities were within target almost continuously, even dropping below target, through 2019, while Reference Lake area salinities were primarily above target (Figure 6). The Reference Marsh sites followed the pattern of the project area sites, but were often lower, especially from 2015 on.

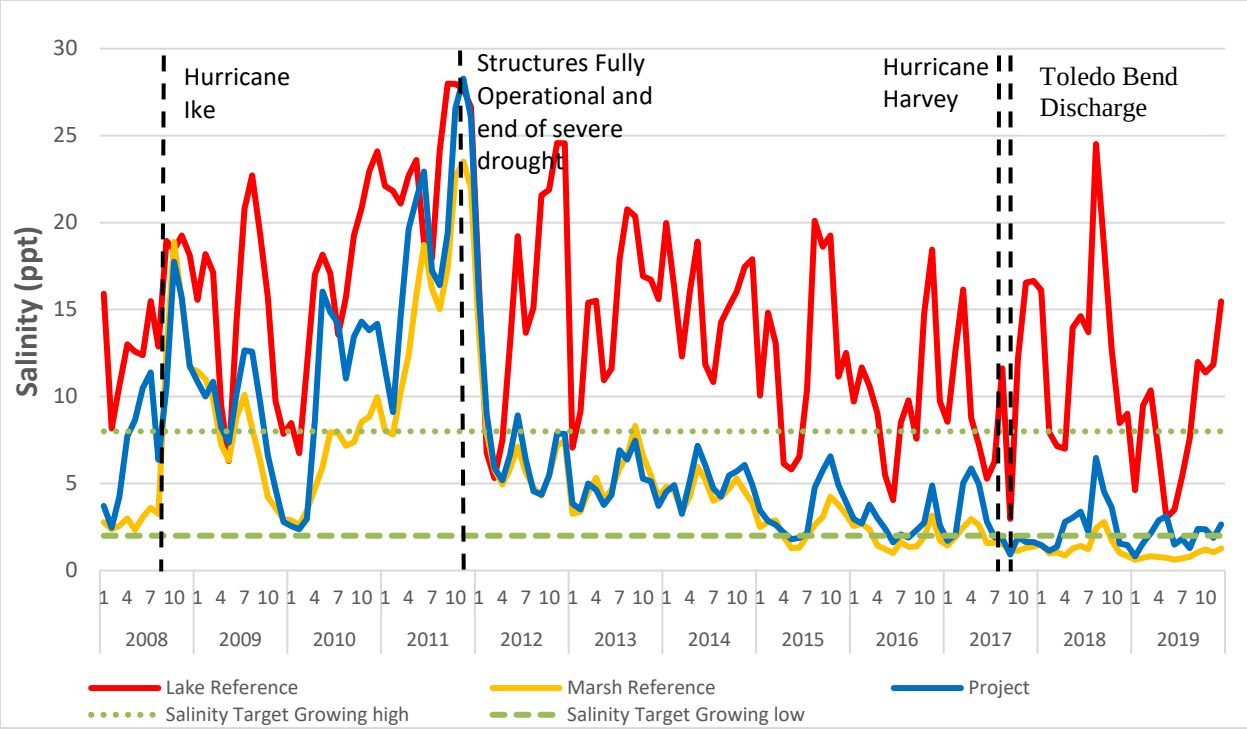


Figure 4. Weekly mean salinities from 2008-2019 at twenty CRMS sites within the CS-23 Project (n=11), Reference Lake (n=2) and Reference Marsh (n=7) areas.

A two way ANOVA on weekly salinity from 2008-2019 of the project sites and two reference locations was performed. The model tested the effects of location and pre or post project construction on weekly salinity levels to isolate and identify the major sources of variability in surface water salinity. Both main effects were significant with location ($F_{2, 2238} = 637.87$, $p < 0.0001$) and pre or post project ($F_{1, 2238} = 897.76$, $p < 0.0001$) having similarly large impacts on the model for different reasons; the project was designed to isolate the project area from the frequently high saline waters of Calcasieu Lake. It appears to have successfully done this while also preventing these waters from passing through the project area into the reference marshes further in the interior of Sabine National Wildlife Refuge. This effect is somewhat confounded by the drought of 2010-2011; but what is clear is that large saline pulses from the lake no longer penetrate into interior marshes as they once did pre-project, even when the lake exceeds 20 ppt per month. This is also evident in the group effect where the project (8.0 ppt) and reference (6.1 ppt) marshes stay much lower than the lake (14.9 ppt) on average for years at a time. With the project and reference marshes also being distinctly different from one another, albeit by a smaller margin, the reference marsh is lower than the project marsh or the lake. Interestingly the interaction of the two effects is also meaningful ($F_{2, 2238} = 22.78$, $p = < 0.0001$) but less so than the main effects by an order of magnitude (Figure 5). Still it does show that the project area's salinity was reduced by -8.2 ppt post construction which is more than the reference marsh (-6.1 ppt) or the lake (-4.7 ppt). This would indicate that the project and the general freshening of the local environment post drought are working in tandem to drive the surface waters of the project area fresher faster than the reference

marsh, and obviously the lake which the project does not effect. However in recent years this has caused the project area to fall below the salinity target especially during the non-growing season.

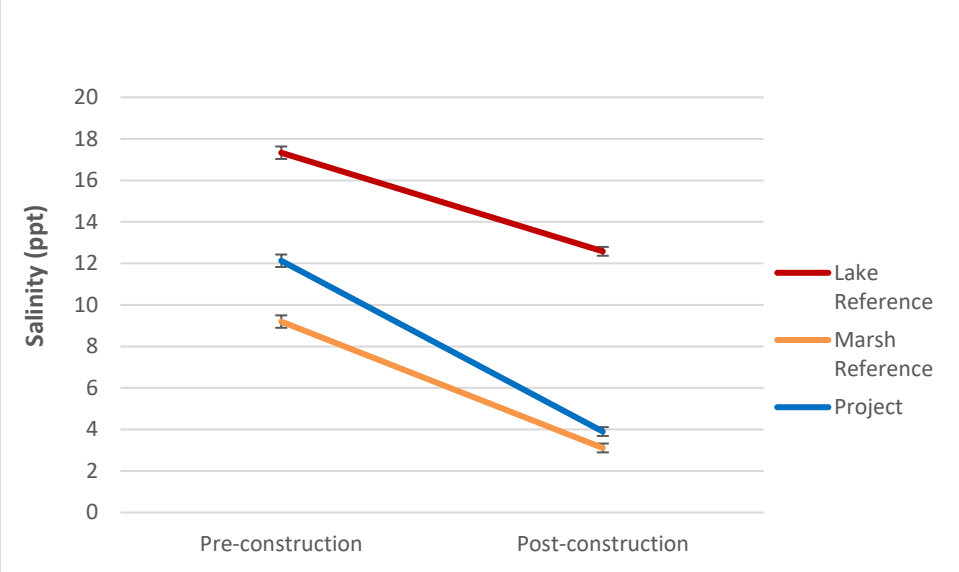


Figure 5. Least square mean salinity (± standard error).

The percent time the salinity was in target was then calculated by weekly means using hourly salinity (ppt) data from 01/01/08 – 12/31/19. From 2008 to 2011 it is evident that the salinities, during the growing and non-growing season were not within the target range as much as after the severe drought of 2011 (Figure 6). Between the 2012 and 2014 growing and non-growing seasons, salinity was on target an average of 92% and was never below target. From 2015 to 2019 the salinities have increasingly fell below the target range more and more frequently, and though the project has met the goal to reduce the occurrence of salinities that exceed target levels, it has not met the goal of maintaining salinities at a level to support intermediate to brackish marsh. Maintaining a fresh water project area for extended periods can have detrimental impacts when the salinity levels increase. Salinities within the more interior reference sites, being further from the water control structures, were fresher than the project, nearing 100% below the growing season target within three of the last five years. The Reference Lake sites are saline sites with connectivity to the Calcasieu Ship Channel and thus are often above the target thresholds set for the project area.

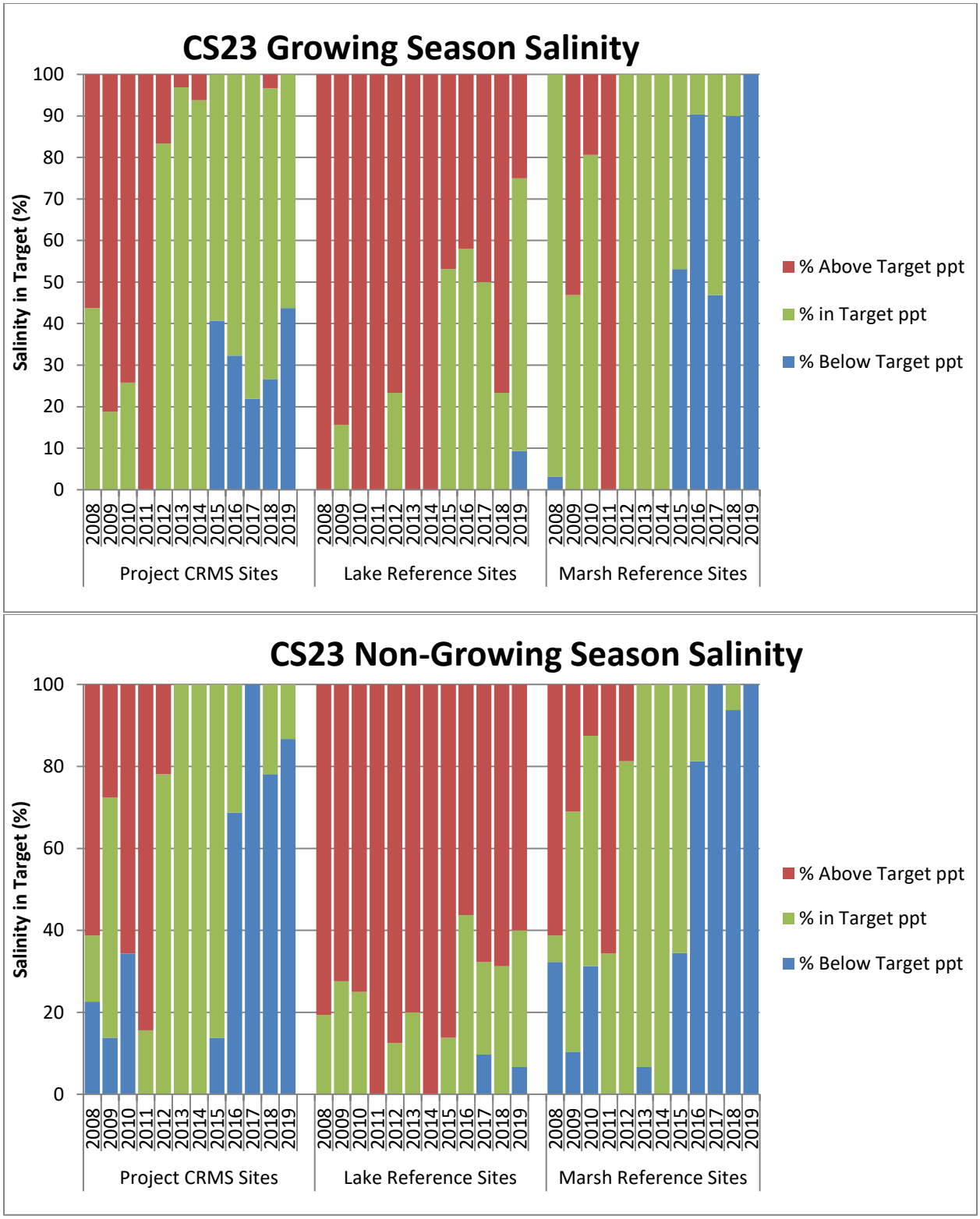


Figure 6. Percentage of the year that weekly average salinity levels were below target, in target, and above target range for CRMS sites within the project (n=8) and reference (n=4) areas for years 2008 – 2019.

i. Water Level

Water level data were collected hourly at nineteen CRMS sites; eleven are CRMS sites located within the CS-23 project area, two are CRMS sites on the perimeter of Calcasieu Lake (Reference Lake), and six are located in the interior marsh west of the CS-23 project area (Reference Marsh).

Monthly means of adjusted water level (geoid 12A) relative to the marsh surface were calculated from CRMS hourly data from 2008-2019 (Figure 7). The highest water levels occurred in September 2017 when average water levels reached 2.57 ft after abundant rainfall, due to Hurricane Harvey, caused for the discharge of excess water from the Toledo Bend reservoir. The water levels in the project area were higher than the 2.33 ft following the passage of Hurricane Ike in Sept 2008. From 2009 to 2011 water levels were varying with levels being higher at times within the project sites when compared to the reference sites. The lowest water levels of 0.55 ft. (NAVD) were recorded in January 2011. After December 2011, when structures became fully operational, water levels had less variance but were overall higher within the project area, near the high end of the target water level. Since 2015, water levels within the project, as well as the Reference Marsh sites are primarily above the target water level goal. Water levels have been higher coastwide since 2015 in the receiving basins, resulting in higher tides and elevated water levels causing above target water levels to occur more often within the project area. The ability of water to exit from within the project area on normal operations is restricted due to sea level rise and the structure's limited cross sectional area. In addition, Hurricane Rita in 2005 and Hurricane Ike in 2008 caused the canal system within the project area to become clogged with sediment and vegetation restricting the natural flows of water, thus further compounding the drainage challenges for the project area (Figure 8).

Weekly Inundation was compared between project and reference sites using a two-way analysis of variance (ANOVA). The model tested the effects of location and pre- or post- project construction on weekly marsh inundation in feet to isolate and identify the major sources of variability in marsh inundation. The analysis showed the project is significantly flooded more often post-construction due to high water levels from 2015-2019 ($F_{1,2373} = 191.85$, $p < 0.0001$). The analysis also showed the reference lake sites are significantly less flooded than the project and reference marsh areas ($F_{1,2373} = 158.65$, $p < 0.0001$). There was no difference between the project area sites and the more interior reference sites indicating that the change may be due to factors other than project construction, most likely sea level rise.

The ability to fully operate the structures during the growing season is critical in maintaining a salinity and water level balance for vegetation to regenerate. Under the current conditions, the project is not meeting the goal to minimize frequency and duration of marsh flooding events. The growing season is heavily influenced by south winds, higher tides and elevated water levels that limit the times water can flow out of the system causing above target water levels to occur more often within the project area. The non-growing season is influenced by frontal passages, north winds which lower outside water levels which allow for increased openings and greater opportunities to maintain water levels within the target range.

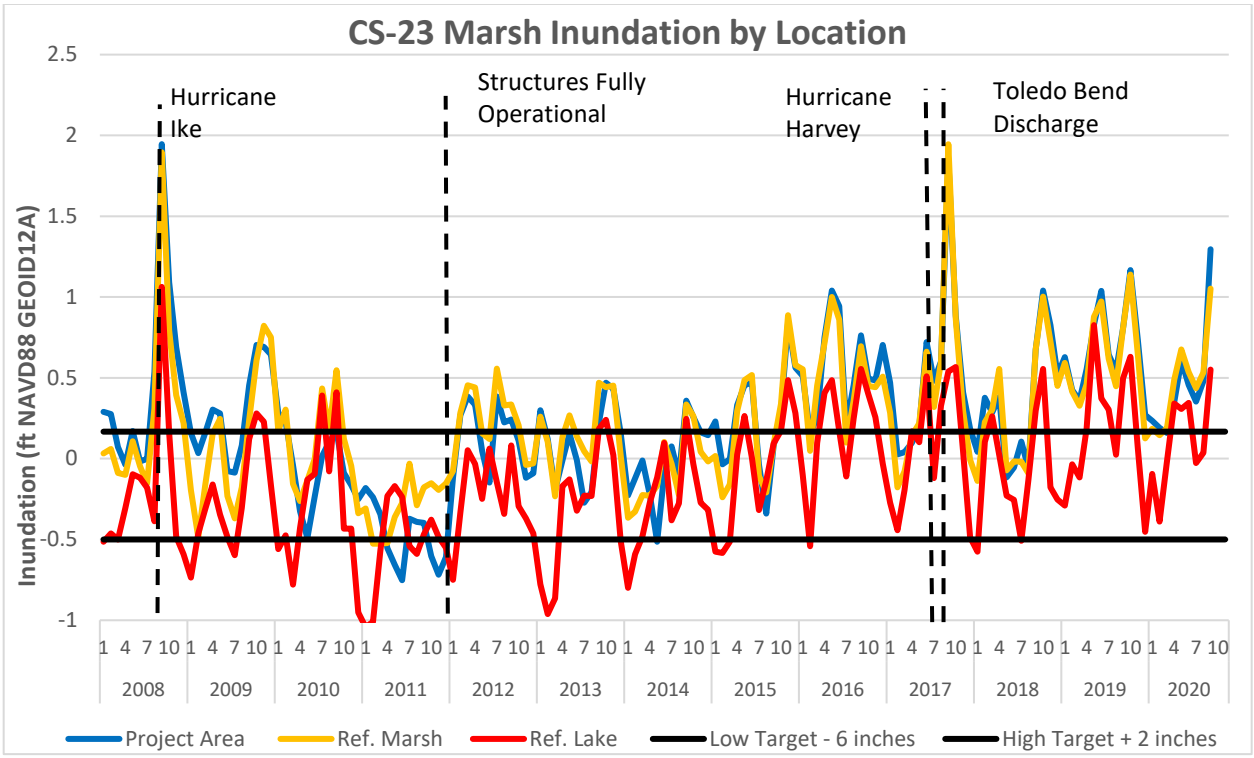


Figure 7. Monthly average inundation for CRMS sites located within the Project (n=11), Reference Lake (n=2), and Reference Marsh (n=6) areas for years 2008 to 2019 along with target management elevations.

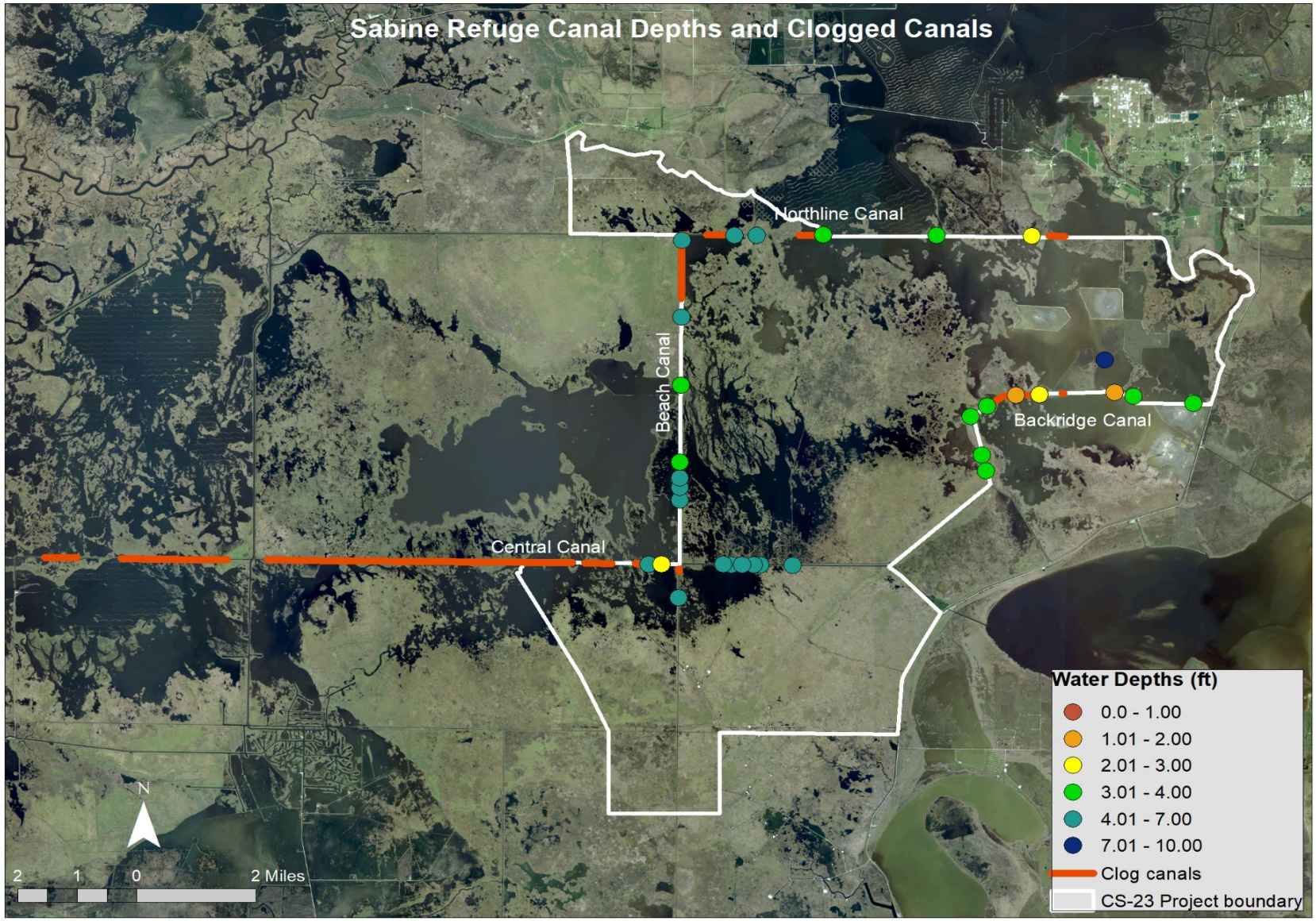


Figure 8. Canal Depths and clogged canals within the CS-23 project boundary.

Vegetation

Vegetation data were analyzed for 11 CRMS project sites, two Reference Lake CRMS sites, and six Reference Marsh CRMS sites. The CS-23 project area has met the goal of maintaining an existing intermediate and brackish vegetation community from 2006 to 2019. Vegetation data do indicate that the marsh is getting fresher, though, with brackish and saline marsh being replaced by intermediate and fresh marsh.

Marsh community types were assigned to each CRMS site by an artificial neural network unsupervised classification system that uses species composition (relative cover) data collected annually from the sites (Snedden 2019). Within the project area, communities at the beginning of the time frame are reduced to only wiregrass (primarily *Spartina patens*) by the drought of 2010-2011 (Figure 9). Since then, the proportion of non-wiregrass communities has increased through time and also shifted. The three-square community (primarily *Schoenoplectus americanus*) has disappeared, with the Paspalum and Roseau Cane communities steadily increasing through time, indicating a freshening species composition. Within the reference areas, conditions have been more uniform through time, except for a couple of outlier years, related primarily to drought.

The FQI for the project area shows a recovery period from Hurricanes Rita and Ike until 2010, where the project was increasing in cover and FQI score (Figure 10). Since 2010, cover has remained high through all years, except during the flood of 2016. The vegetation community has been dominated by *Spartina patens* through all years. In more recent years, due to the flooded conditions, more salt-tolerant sub-species such as *Schoenoplectus americanus*, *Bolboschoenus robustus*, and *Distichlis spicata* have been replaced by fresher species such as *Typha latifolia*, *Paspalum vaginatum*, and *Schoenoplectus californicus*. Multiple instances of either detached/floating marsh or shallow expansion have even been observed at project area CRMS sites due to the prolonged inundation. These conditions were noted at CRMS0635, CRMS0638, CRMS0642 and CRMS0677. Persistent flooding weakens the root systems of marsh vegetation making it vulnerable to removal during hurricanes or other high energy events.

The Reference Marsh area has shown a similar trend to the project area sites, recovering from the hurricanes by 2010 and trending toward fresher species. *Spartina patens* is the dominant species with increasing amounts of fresher subspecies such as *Paspalum vaginatum*, *Schoenoplectus californicus*, and *Phragmites australis*. The Reference Lake area has maintained a saltier cohort of herbaceous species making up the vegetation communities with most ranging from brackish to saline, as fresh and intermediate species are completely removed from the landscape by 2011. This area is dominated by *Spartina patens*, *Spartina alterniflora* and *Juncus roemarianus*.

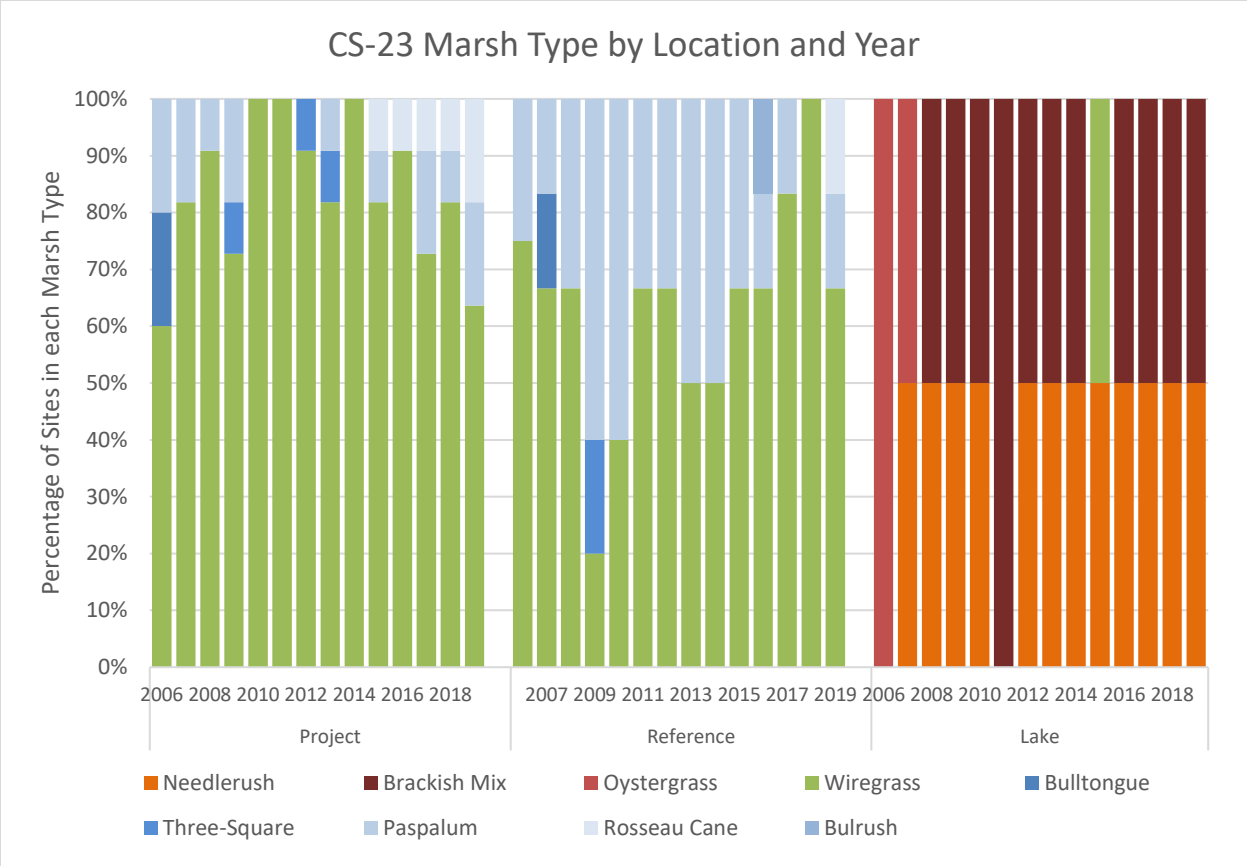


Figure 9. Marsh community types within the Project (n=11), Reference Lake (n=2) and Reference Marsh sites (n=6) in years 2006-2019.

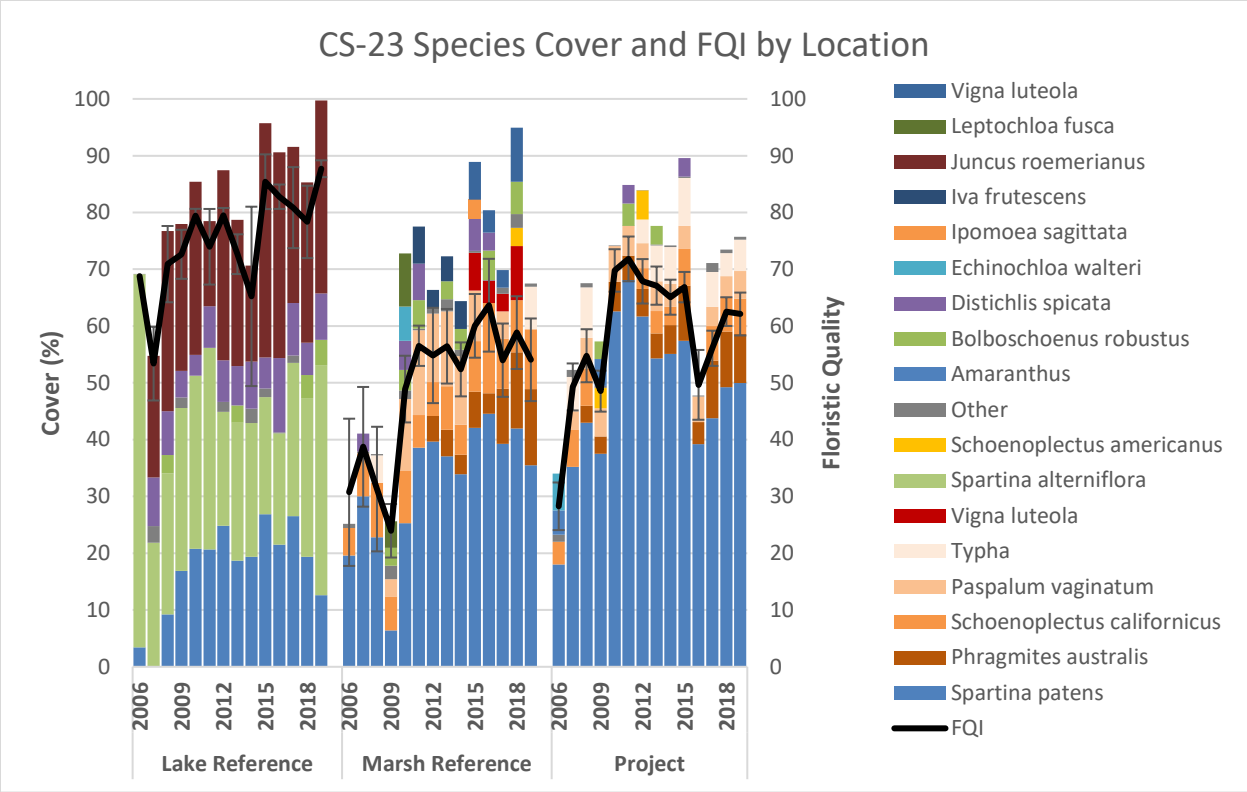


Figure 10. Percent coverage and Floristic Quality Index of species within the Project (n=11), Reference Lake (n=2) and Reference Marsh sites (n=6) in years 2006-2019. The CC scores represent the quality of individual species from 1 to 10 where 1 represents disturbance species and 10 indicates stability.

Submerged Aquatic Vegetation

SAV was collected in 1999 pre-construction and in 2004, 2009, 2014 and 2018 post-construction. Percent occurrence by species was calculated on all SAV transects in the project and reference areas (Figure 11). *Ruppia maritima* was present in the project area for all sampling periods although it was minimal in 2009 and 2014 with only 2 percent occurrence. The reference area had a presence of *Ruppia* in 1999 (14%), 2004 (36%), 2014 (1%) and 2018 (1%) although it was minimal after 2009. In 2004 the project area experienced an abundance of additional species besides *Ruppia maritima*. The species of *Potomageton pectinatus, Najas guadalupensis, Chara, Nymphaea odorata, Utricularia gibba* and *algae* were present but these species were not present within the reference area. In 2018, the project area saw an increase of Ruppia maritima occurring 26% but the Ruppia was not present in the reference area. Therefore, the project did meet the goal of increasing the occurrence of SAV since construction. However, the occurrence of SAV is still not at the level that it was in 2004. The dependence of water clarity, water temperature, water depth and salinity play a major role in the SAV occurrences. The fresher conditions of recent years have undoubtedly benefited SAV within the project area. However, Hurricane Rita in 2005 created large areas of marsh loss and deeper ponds that are not suitable for SAV.

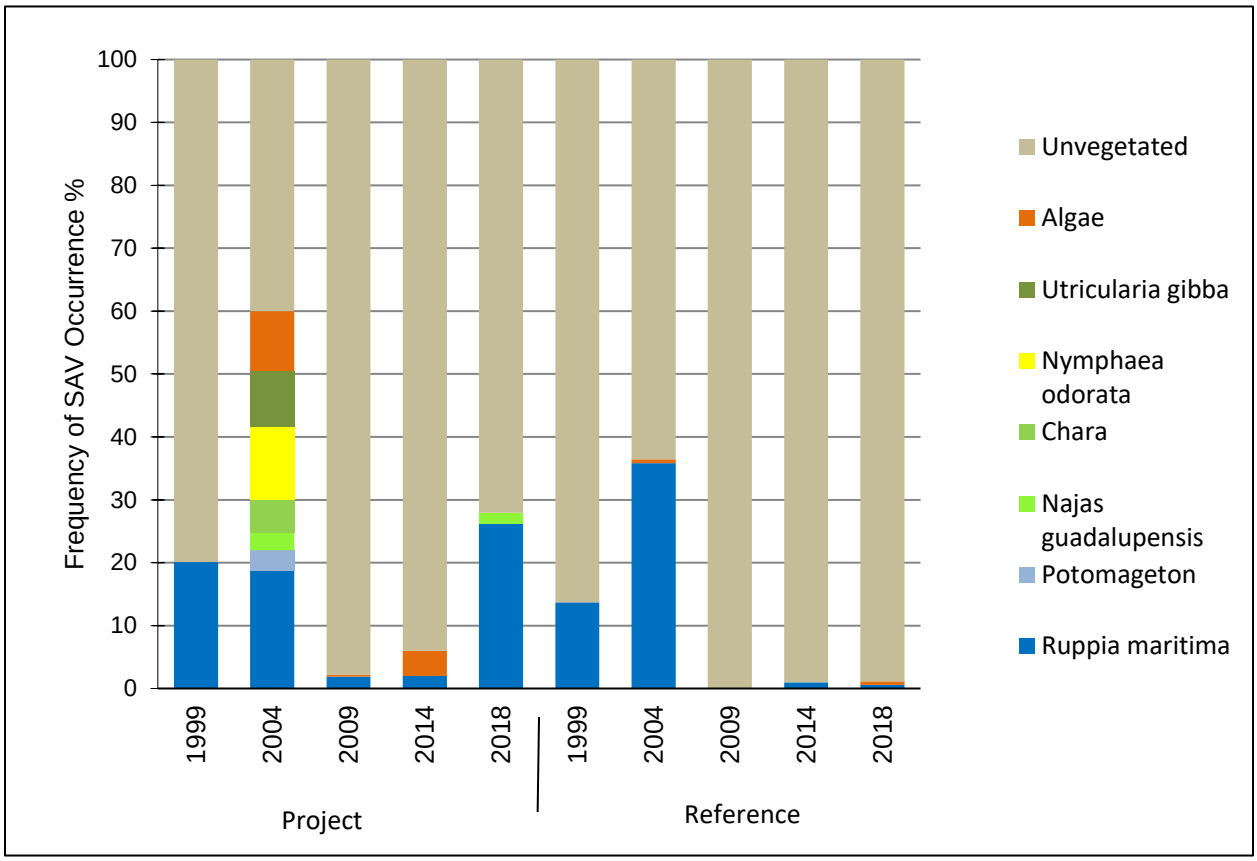


Figure 11. Percent occurrences of SAV within the project and reference area for the 1999, 2004, 2009, 2014 and 2018 sampling periods.

CRMS Supplemental:

Soil Porewater

Soil interstitial (porewater) salinity data were collected from 10 and 30 cm depths at 11 CRMS project sites, two Reference Lake CRMS sites, and six Reference Marsh CRMS sites (Figure 12). Monthly porewater data were averaged across depths, then yearly means were calculated for the project and reference areas for years 2006 – 2019. The Project and Reference Marsh area porewater salinities have been similar through time and much lower than the Reference Lake area for all years. An increase in soil salinities occurred in all areas due to the severe 2011 drought, but the increase was nearly equal within each of the areas. Project porewater salinities ranged from 9 - 16 ppt during 2006 – 2014 which is within the brackish range of vegetative species occurring in the project area. From 2015 – 2019, project porewater salinities have continually decreased to below 5 ppt and fell to within the intermediate vegetation range. The Reference Marsh area salinities were slightly lower than project salinities from 2008-2011, but became nearly equal following the drought. The Reference Lake area porewater salinities ranged from 15 – 26 ppt

which fall within the saline range and is indicative of the vegetation species occurring within the reference area.

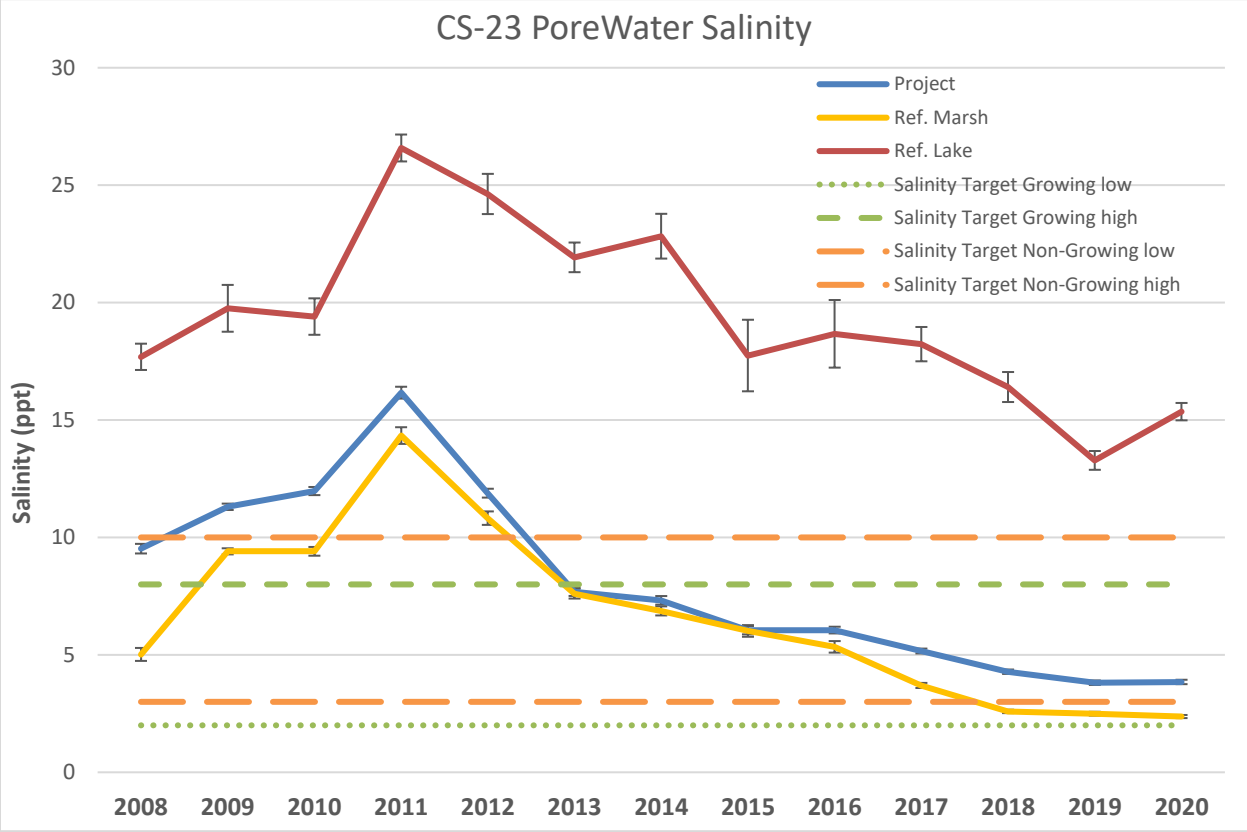


Figure 12. Yearly means of CRMS porewater salinity data within the Project (n=11), Reference Lake (n=2) and Reference Marsh (n=6) areas collected at 10 and 30 cm and averaged (mean ± standard error).

Marsh Elevation Change

Elevation change and accretion data were collected at eleven CRMS sites within the Project area, two sites within the Reference Lake area and six sites within the Reference Marsh area (Figure 13). Cumulative elevation change at the project sites has been static overall. The marshes gained elevation following Hurricane Ike, but lost that elevation during the drought of 2010-2011. Again elevation gain occurred from 2013-2015, but was lost during the flood of 2016. The project area has seen a positive trajectory through 2020, but has just recovered to the level of 2009. As mentioned in the vegetation section, in response to the chronic flooding of recent years, some areas within the project area have detached and became floating marshes or exhibited shallow expansion. These conditions were observed at CRMS0635, 638, 642, and 677. CRMS0635 detached and became floating from 2016 – 2018 following prolonged flooding and herbivory (Figure 14). Shallow expansion also occurred at this site following Hurricane Ike. Shallow Expansion is prevalent at CRMS0642 (Figure 15). This site is located in a spongy *Typha latifolia* marsh that is

chronically flooded. Cumulative elevation change at the interior Reference Marsh sites has followed a similar trajectory to the project area sites, but has shown greater elevation loss through time. These sites lost more elevation during the drought of 2010 and 2011 and struggled to regain the lost elevation capitol. Perpetual flooding is bad for surface elevation trajectories. Flood-stressed areas typically have lower productivity resulting in greater elevation and land loss, especially during high-energy storm events. In addition, sea level rise will exacerbate flooding into the future.

The Reference Lake area stations which are located along the rim of Calcasieu Lake experience natural sedimentation processes from tidal cycles and high water levels and thus higher elevation gain. The typical cycle in these locations is accretion building up along the lake rim contiguous to the ship channel as interior areas are cut off and undergo sedimentation starvation.

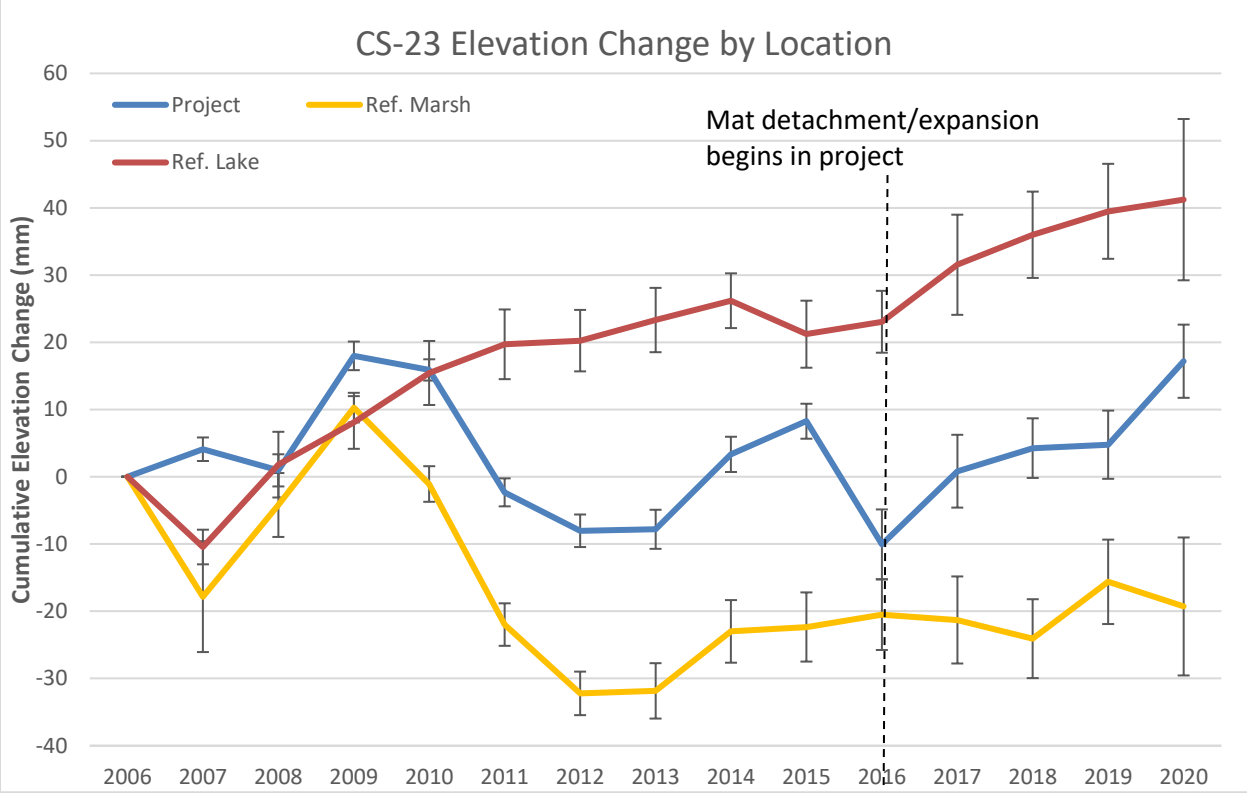


Figure 13. Cumulative elevation change (mm) collected at rod-surface elevation tables (RSET) at CS-23 project (n=11), Reference Lake (n=2), and Reference Marsh (n=6) areas over time.

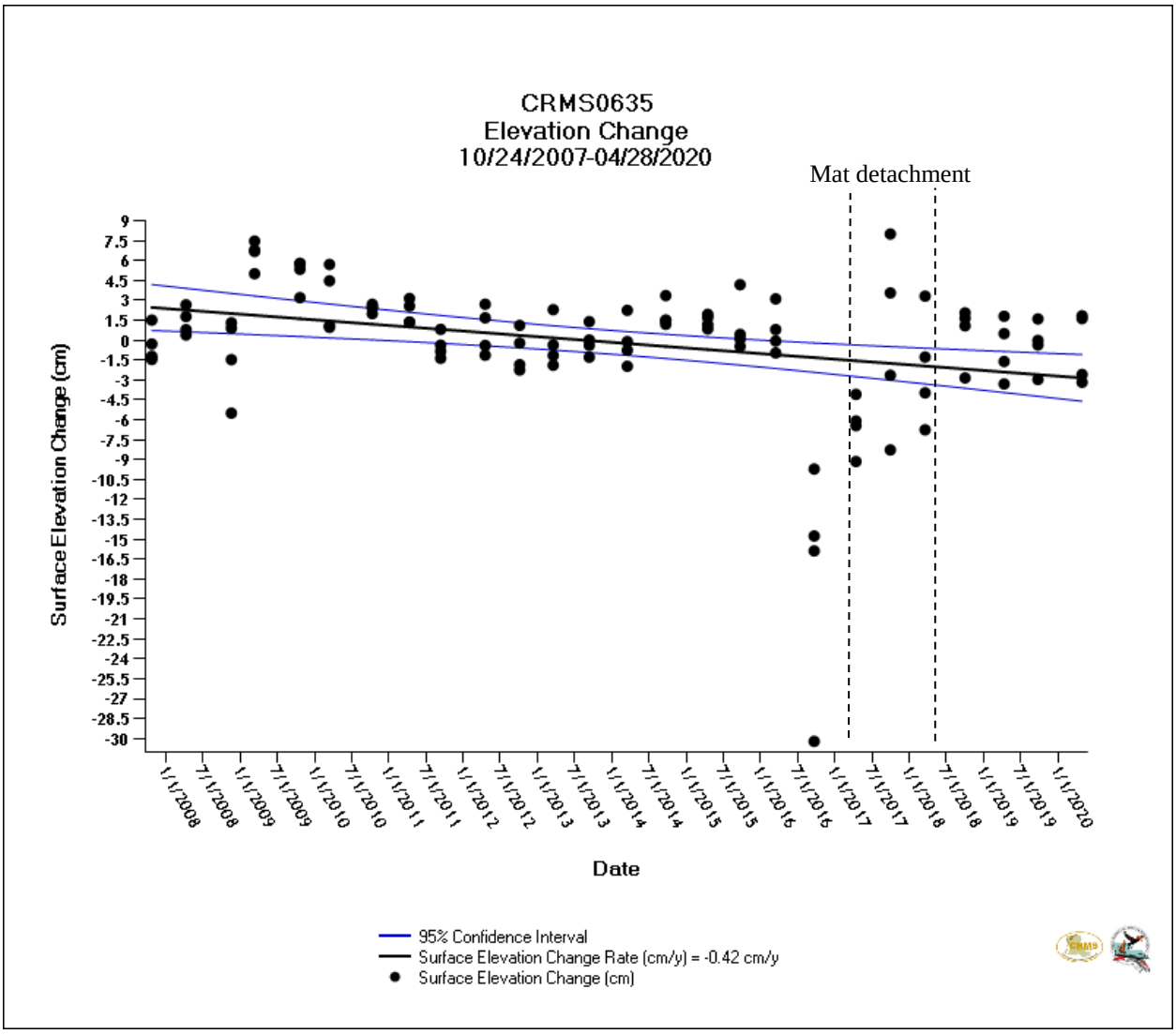


Figure 14. Surface Elevation change at CRMS0635 within the CS-23 project area.

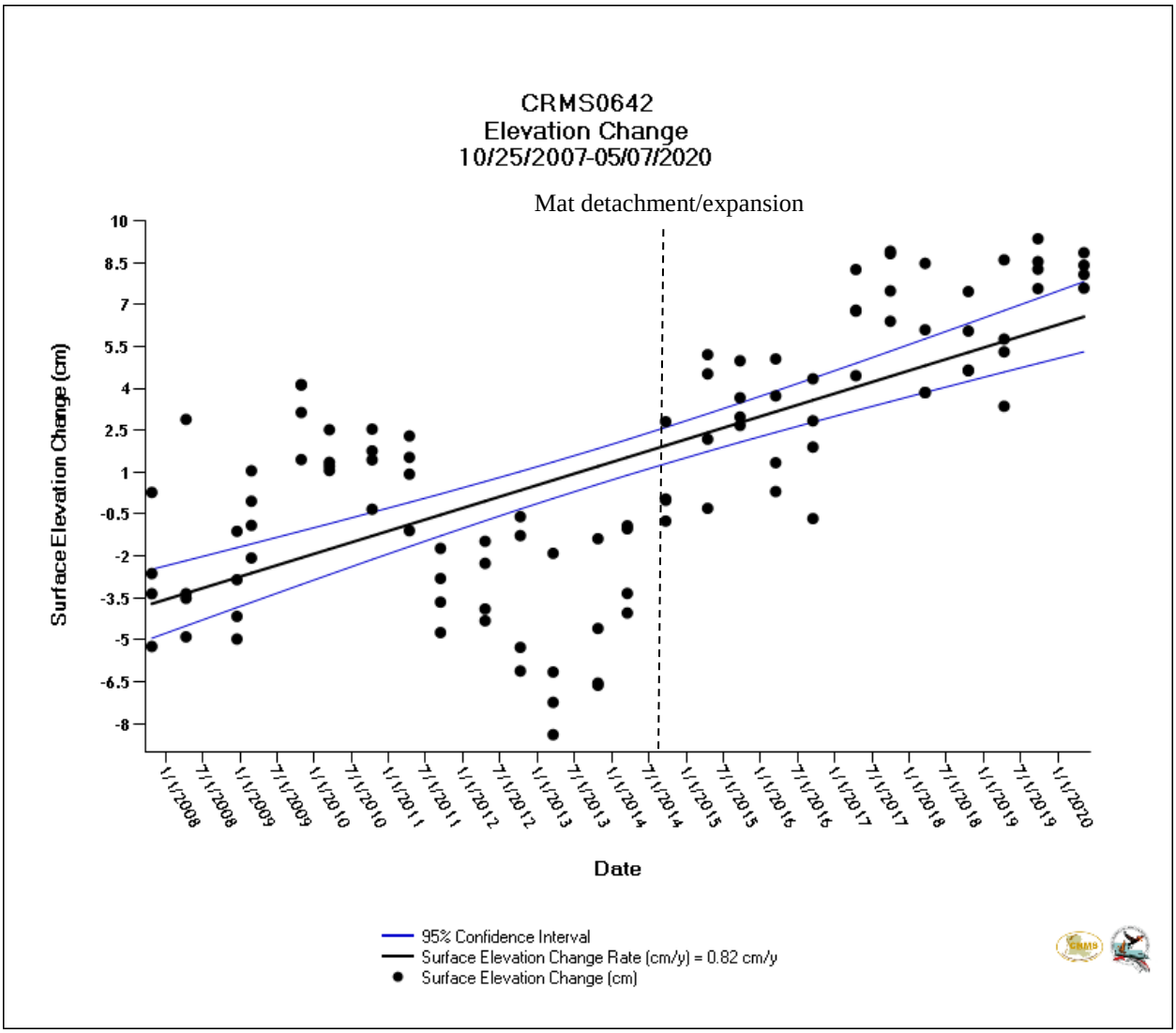
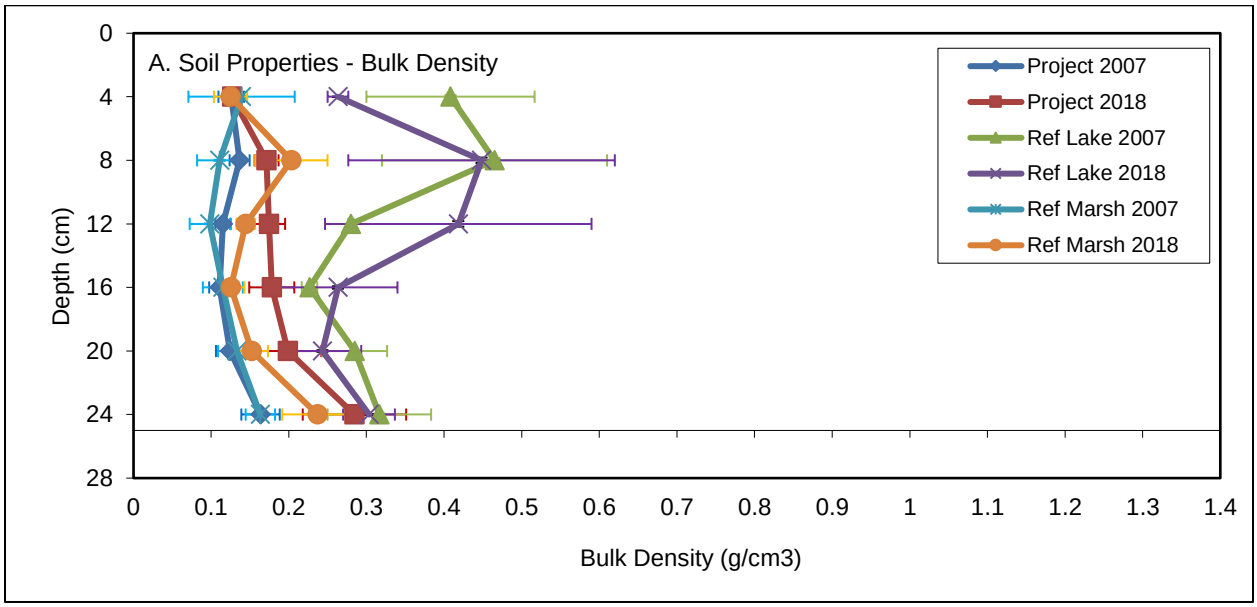


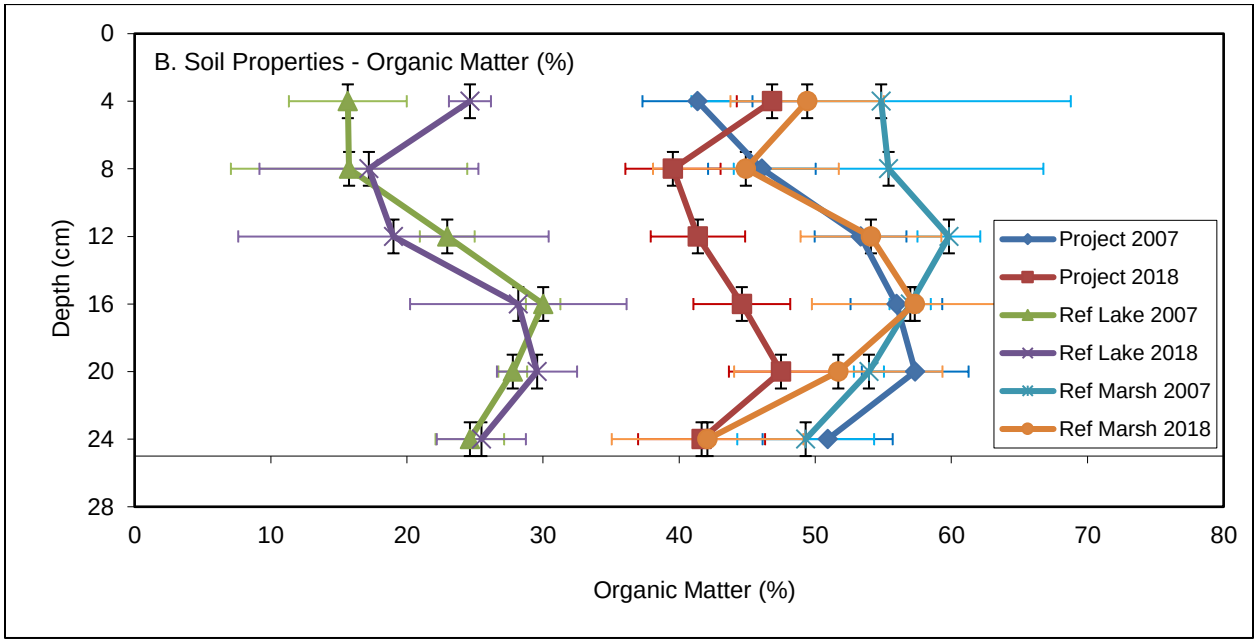
Figure 15. Surface Elevation change at CRMS0642 within the CS-23 project area.

Soil Bulk Properties

Soil samples were collected in 2007 upon establishment of the CRMS project and reference sites and again in 2018. Figures for mean bulk density and organic matter are presented in figures 16a and 16b. Bulk density was highest in the reference lake sites through both sampling periods (Figure 16a). The Reference Lake CRMS sites show a decrease in bulk density, and conversely an increase in % organic matter, from 12-16 cm which can likely be attributed to organic deposition occurring at some point in time. Percent organic content was higher in the project and reference marsh sites than the reference lake sites throughout all depth profiles (Figure 16b). This is likely due to the influence of the structures ability to deter natural tidal cycles and to reduce the ability of sedimentation to occur within the interior marshes. Interestingly, percent organic matter

decreased ~10% in the 2018 sampling of the project area sites at lower depths. A slight increase in bulk density was also noted.





Figures 16a and 16b. Soil Bulk density (A) and % organic matter (B) of CRMS sites within project and reference areas for 2007 and 2018. Mean ± SE.

V. Conclusions

a. Project Effectiveness

Since becoming fully operational, the water control structures of the project have been very effective at curtailing saltwater entry into the project area, to a fault. Under the current management regime, salinities have fallen below values necessary to sustain the existing marsh type. In addition, the project has not been successful in reducing the frequency and duration of marsh flooding events. Prolonged flooding, due to sea level rise and the obstructed canal system, have increased since 2015. This flooding strains the marsh vegetation and leads to depressed elevation change rates within the project area and further into the interior of the refuge. Although largely due to two major hurricanes, land loss has occurred within the project area and will likely increase in the future under the current conditions.

b. Recommended Improvements

Although the water management plan is followed and manager's discretion is used when appropriate, after review of the water level data from 2011 to 2015, it is apparent that a more active management in structure operations or a change in the water management plan for water levels could alleviate some of the flooding problems. The ability to fully operate the structures during the growing season is critical in maintaining a salinity and water level balance for vegetation to regenerate. At a minimum, the High Water Provision of the operations plan should be used when conditions call for it.

In addition, water flow through the project area is hampered due to obstructions in the canal system that occurred during Hurricanes Rita and Ike. A maintenance event to clean these canals would dramatically improve the project's ability to evacuate excess water when conditions allow drainage during high water events.

c. Lessons Learned

Installation instructions should be written for the installation of the pedestal, stem, and actuator, which state the tolerances to be used.

Dual stems should be considered on slide gates for projects such as this to prevent binding between the gate and guide slots and wear and tear on the actuator and gate mechanisms.

Structural management must adapt to rising sea level in order to meet project goals.

VI. Literature Cited

Adams, R. D., P. J. Banas, R. H. Baumann, J. H. Blackmon, and W. G. McIntire 1978. Shoreline erosion in coastal Louisiana: inventory and assessment. Baton Rouge: Louisiana Department of Transportation and Development, Coastal Resources Program. 139 pp.

Chabreck, R. H. and G. Linscombe 1978. Vegetative type map of the Louisiana coastal marshes. New Orleans: Louisiana Department of Wildlife and Fisheries. Scale1:62,500.

Coastal Protection and Restoration Authority of Louisiana – Operations Division. 2012. 2012/2013 Annual Inspection Report for Replace Sabine Refuge Water Control structures at Headquarters Canal, West Cove Canal, and Hog Island Gully (CS-23). Louisiana Coastal Protection and Restoration Authority.

Couvillion, B.R., Beck, Holly, Schoolmaster, Donald, and Fischer, Michelle, 2017, Land area change in coastal Louisiana 1932 to 2016: U.S. Geological Survey Scientific Investigations Map 3381, 16 p. pamphlet, https://doi.org/10.3133/sim3381.

Todd M. Folse, Thomas E. McGinnis, Leigh A. Sharp, Jonathan L. West, MelissaK. Hymel, John P. Troutman, Dona Weifenbach, William M. Boshart, Laurie B. Rodrigue, Danielle C. Richardi, W. Bernard Wood, C. Mike Miller, Elizabeth M. Robinson, Angelina M. Freeman, Camille L. Stagg, Brady R. Couvillion, and Holly J. Beck. 2020. A Standard Operating Procedures Manual for the Coastwide Reference Monitoring System-Wetlands and the System-Wide Assessment and Monitoring Program: Methods for Site Establishment, Data Collection, and Quality Assurance/Quality Control. Louisiana Coastal Protection and Restoration Authority. Baton Rouge, LA. 252 pp.

Nyman, J. A., and R. H. Chabreck 1996. Some effects of 30 years of weir management on coastal marsh aquatic vegetation and implications to waterfowl management. Gulf of Mexico Science 14: 16-25.

O'Neil, T. 1949. The muskrat in the Louisiana coastal marshes. Louisiana Wildlife and Fisheries Commission New Orleans, Louisiana 159pp.

Sasser, C.E. and Visser, J.M., 2008, Coastwide vegetation data collection project: final report: Baton Rouge, La., Louisiana State University Agricultural Center.

Snedden, G.A., 2019. Patterning emergent marsh vegetation assemblages in coastal Louisiana, USA, with unsupervised artificial neural networks. Applied Vegetation Science 22: 213-229. DOI: 10.1111.avsc.12425

Steyer, G. D., R. C. Raynie, D. L. Steller, D. Fuller, and E. Swensen 1995 (revised 2000). Quality management plan for Coastal Wetlands Planning, Protection, and Restoration Act monitoring program. Open-file series no. 95-01. Baton Rouge: Louisiana Department of Natural Resources, Coastal Restoration Division. 112 pp plus appendices

United States Fish and Wildlife Service, Sabine National Wildlife Refuge 1999. Final Environmental Assessment. Replacement of Water control structures at Hog Island Gully, West Cove Canal, and Headquarters Canal. Hackberry, Louisiana: Sabine National Wildlife Refuge. 75 pp.

APPENDIX A
(Inspection Photographs)

Photo No.1, Hog Island Gully Structure looking from the Hwy 27 side.

Photo No. 2, Hog Island Gully Structure from the Calcasieu Lake side– gates being exercised and in open position

Photo No. 3, Headquarters Structure with outside flapgates flapping

Photo No. 4, Headquarters Structure marsh side culverts with riprap

Photo No. 5, West Cove Canal Calcasieu Lake side of structure with flapgate flapping

Photo No. 6, West Cove Canal from Hwy 27 side – gates being exercised and in open position

APPENDIX B
(Three Year Budget Projection)

SNWR STRUCTURES/ CS-23 / PPL 3

Three-Year Operations & Maintenance Budgets 07/01/2016 - 06/30/2019

Project Manager	O & M Manager	Federal Sponsor	Prepared By
Darrell Pontiff	*Dion Broussard*	*USFWS*	*Dion Broussard*

	2016/2017 (-17)	2017/2018 (-18)	2018/2019 (-19)
Maintenance Inspection	$ 7,057.00	$ 7,269.00	$ 7,487.00
Structure Operation	$ 5,000.00	$ 5,000.00	$ 5,000.00
State Administration			$ -
Federal Administration			$ -
Maintenance/Rehabilitation			

16/17 Description:

E&D	$ -
Construction	
Construction Oversight	
Sub Total - Maint. And Rehab.	$ -

17/18 Description:

E&D	
Construction	
Construction Oversight	
Sub Total - Maint. And Rehab.	$ -

18/19 Description:

E&D	$ -
Construction	$ -
Construction Oversight	$ -
Sub Total - Maint. And Rehab.	$ -

	2016/2017 (-17)	2017/2018 (-18)	2018/2019 (-19)
Total O&M Budgets	**$ 12,057.00**	**$ 12,269.00**	**$ 12,487.00**

O &M Budget (3 yr Total)	**$ 36,813.00**
Unexpended O & M Budget	**$ 527,306.00**
Remaining O & M Budget (Projected)	**$ 490,493.00**

OPERATION AND MAINTENANCE BUDGET WORKSHEET

SABINE REFUGE STRUCTURES / PROJECT NO. CS-23 / PPL NO. 3 / 2016/2017 (-17)

DESCRIPTION	UNIT	EST. QTY.	UNIT PRICE	ESTIMATED TOTAL
O&M Inspection and Report	EACH	1	$7,057.00	**$7,057.00**
General Structure Maintenance	LUMP	0	$0.00	**$0.00**
Engineering and Design	LUMP	0	$0.00	**$0.00**
Operations Contract	LUMP	1	$5,000.00	**$5,000.00**
Construction Oversight	LUMP	0	$0.00	**$0.00**

ADMINISTRATION

LDNR / CRD Admin.	LUMP	0	$0.00	$0.00
FEDERAL SPONSOR Admin.	LUMP	0	$0.00	$0.00
SURVEY Admin.	LUMP	0	$0.00	$0.00
OTHER				$0.00
			TOTAL ADMINISTRATION COSTS:	**$0.00**

MAINTENANCE / CONSTRUCTION

SURVEY

SURVEY DESCRIPTION:					
Secondary Monument	EACH	0	$0.00	$0.00
Staff Gauge / Recorders	EACH	0	$0.00	$0.00
Marsh Elevation / Topography	LUMP	0	$0.00	$0.00
TBM Installation	EACH	0	$0.00	$0.00
OTHER				$0.00
			TOTAL SURVEY COSTS:	**$0.00**

GEOTECHNICAL

GEOTECH DESCRIPTION:					
Borings	EACH	0	$0.00	$0.00
OTHER				$0.00
			TOTAL GEOTECHNICAL COSTS:	**$0.00**

CONSTRUCTION

CONSTRUCTION DESCRIPTION:					
Rip Rap	LIN FT	TON / FT	TONS	UNIT PRICE	
	0	0.0	0	$0.00	$0.00
	0	0.0	0	$0.00	$0.00
	0	0.0	0	$0.00	$0.00
Filter Cloth / Geogrid Fabric		SQ YD	0	$12.00	$0.00
Navigation Aid		EACH	0	$0.00	$0.00
Signage		EACH	0	$0.00	$0.00
General Excavation / Fill		CU YD	0	$0.00	$0.00
Dredging		CU YD	0	$0.00	$0.00
Sheet Piles (Lin Ft or Sq Yds)			0	$0.00	$0.00
Timber Piles (each or lump sum)			0	$0.00	$0.00
Timber Members (each or lump sum)			0	$0.00	$0.00
Hardware		LUMP	0	$0.00	$0.00
Materials		LUMP	0	$0.00	$0.00
Mob / Demob		LUMP	0	$0.00	$0.00
Contingency		LUMP	0	$0.00	$0.00
General Structure Maintenance		LUMP	0	$0.00	$0.00
OTHER				$0.00	$0.00
OTHER				$0.00	$0.00
OTHER				$0.00	$0.00
				TOTAL CONSTRUCTION COSTS:	**$0.00**

TOTAL OPERATIONS AND MAINTENANCE BUDGET: **$12,057.00**

OPERATION AND MAINTENANCE BUDGET WORKSHEET

SABINE REFUGE STRUCTURES / PROJECT NO. CS-23 / PPL NO. 3 / 2017/2018 (-18)

DESCRIPTION	UNIT	EST. QTY.	UNIT PRICE	ESTIMATED TOTAL
O&M Inspection and Report	EACH	1	$7,269.00	**$7,269.00**
General Structure Maintenance	LUMP	0	$0.00	**$0.00**
Engineering and Design	LUMP	0	$0.00	**$0.00**
Operations Contract	LUMP	1	$5,000.00	**$5,000.00**
Construction Oversight	LUMP	0	$0.00	**$0.00**

ADMINISTRATION

LDNR / CRD Admin.	LUMP	0	$0.00	$0.00
FEDERAL SPONSOR Admin.	LUMP	0	$0.00	$0.00
SURVEY Admin.	LUMP	0	$0.00	$0.00
OTHER				$0.00
			TOTAL ADMINISTRATION COSTS:	**$0.00**

MAINTENANCE / CONSTRUCTION

SURVEY

SURVEY DESCRIPTION:					
Secondary Monument	EACH	0	$0.00	$0.00
Staff Gauge / Recorders	EACH	0	$0.00	$0.00
Marsh Elevation / Topography	LUMP	0	$0.00	$0.00
TBM Installation	EACH	0	$0.00	$0.00
OTHER				$0.00
			TOTAL SURVEY COSTS:	**$0.00**

GEOTECHNICAL

GEOTECH DESCRIPTION:					
Borings	EACH	0	$0.00	$0.00
OTHER				$0.00
			TOTAL GEOTECHNICAL COSTS:	**$0.00**

CONSTRUCTION

CONSTRUCTION DESCRIPTION:					
Rip Rap	LIN FT	TON / FT	TONS	UNIT PRICE	
	0	0.0		$0.00	$0.00
	0	0.0	0	$0.00	$0.00
	0	0.0	0	$0.00	$0.00
Filter Cloth / Geogrid Fabric		SQ YD	0	$12.00	$0.00
Navigation Aid		EACH	0	$0.00	$0.00
Signage		EACH	0	$0.00	$0.00
General Excavation / Fill		CU YD	0	$0.00	$0.00
Dredging		CU YD	0	$0.00	$0.00
Sheet Piles (Lin Ft or Sq Yds)			0	$0.00	$0.00
Timber Piles (each or lump sum)			0	$0.00	$0.00
Timber Members (each or lump sum)			0	$0.00	$0.00
Hardware		LUMP	0	$0.00	$0.00
Materials		LUMP	0	$0.00	$0.00
Mob / Demob		LUMP	0	$0.00	$0.00
Contingency		LUMP	0	$0.00	$0.00
General Structure Maintenance		LUMP	0	$0.00	$0.00
OTHER				$0.00	$0.00
OTHER				$0.00	$0.00
OTHER				$0.00	$0.00
				TOTAL CONSTRUCTION COSTS:	**$0.00**

TOTAL OPERATIONS AND MAINTENANCE BUDGET: **$12,269.00**

OPERATION AND MAINTENANCE BUDGET WORKSHEET

SABINE REFUGE STRUCTURES / PROJECT NO. CS-23 / PPL NO. 3 / 2018/2019 (-19)

DESCRIPTION	UNIT	EST. QTY.	UNIT PRICE	ESTIMATED TOTAL
O&M Inspection and Report	EACH	1	$7,487.00	**$7,487.00**
General Structure Maintenance	LUMP	0	$0.00	**$0.00**
Engineering and Design	LUMP	0	$0.00	**$0.00**
Operations Contract	LUMP	1	$5,000.00	**$5,000.00**
Construction Oversight	LUMP	0	$0.00	**$0.00**

ADMINISTRATION

LDNR / CRD Admin.	LUMP	0	$0.00	$0.00
FEDERAL SPONSOR Admin.	LUMP	0	$0.00	$0.00
SURVEY Admin.	LUMP	0	$0.00	$0.00
OTHER				$0.00
			TOTAL ADMINISTRATION COSTS:	**$0.00**

MAINTENANCE / CONSTRUCTION

SURVEY

SURVEY DESCRIPTION:					
Secondary Monument	EACH	0	$0.00	$0.00
Staff Gauge / Recorders	EACH	0	$0.00	$0.00
Marsh Elevation / Topography	LUMP	0	$0.00	$0.00
TBM Installation	EACH	0	$0.00	$0.00
OTHER				$0.00
			TOTAL SURVEY COSTS:	**$0.00**

GEOTECHNICAL

GEOTECH DESCRIPTION:					
Borings	EACH	0	$0.00	$0.00
OTHER				$0.00
			TOTAL GEOTECHNICAL COSTS:	**$0.00**

CONSTRUCTION

CONSTRUCTION DESCRIPTION:					
Rip Rap	LIN FT	TON / FT	TONS	UNIT PRICE	
	0	0.0	0	$0.00	$0.00
	0	0.0	0	$0.00	$0.00
	0	0.0	0	$0.00	$0.00
Filter Cloth / Geogrid Fabric		SQ YD	0	$12.00	$0.00
Navigation Aid		EACH	0	$0.00	$0.00
Signage		EACH	0	$0.00	$0.00
General Excavation / Fill		CU YD	0	$0.00	$0.00
Dredging		CU YD	0	$0.00	$0.00
Sheet Piles (Lin Ft or Sq Yds)			0	$0.00	$0.00
Timber Piles (each or lump sum)			0	$0.00	$0.00
Timber Members (each or lump sum)			0	$0.00	$0.00
Hardware		LUMP	0	$0.00	$0.00
Materials		LUMP	0	$0.00	$0.00
Mob / Demob		LUMP	0	$0.00	$0.00
Contingency		LUMP	0	$0.00	$0.00
General Structure Maintenance		LUMP	0	$0.00	$0.00
OTHER				$0.00	$0.00
OTHER				$0.00	$0.00
OTHER				$0.00	$0.00
				TOTAL CONSTRUCTION COSTS:	**$0.00**

TOTAL OPERATIONS AND MAINTENANCE BUDGET: **$12,487.00**

APPENDIX C
(Field Inspection Notes)

MAINTENANCE INSPECTION REPORT CHECK SHEET

Project No. / Name:CS-23 Sabine Refuge Structure Replacement

Date of Inspection: November 12, 2015 Time: 11:00 a.m.

Structure No. Hog Island Gully Canal

Inspector(s): Dion Broussard (CPRA)
Daryl Clark (USFWS)
Brandon Samson (NRCS) for other inspections

Structure Description: Control Structure

Water Level Inside:N/A Outside: N/A

Type of Inspection: Annual

Weather Conditions: Cloudy skies and cold temperatures

Item	Condition	Physical Damage	Corrosion	Photo #	Observations and Remarks
Steel Bulkhead / Caps	N/A				
Steel Grating	Good				
Gates	Good			1 & 2	
Electrical	Good				
Hardware					
Fencing	Good			1	
Timber Piles	Good				
Timber Wales	N/A				
Actuators	Good			1	Gate 2A needs acuator motor replacement.
Cables	Good				
Signage /Supports	Good				
Rip Rap	Good				
Earthen Embankment	N/A				

What are the conditions of the existing levees?
Are there any noticeable breaches?
Settlement of rock plugs and rock weirs?
Position of stoplogs at the time of the inspection?
Are there any signs of vandalism?

MAINTENANCE INSPECTION REPORT CHECK SHEET

Project No. / Name:CS-23 Sabine Refuge Structure Replacement — Date of Inspection: November 12, 2015 Time: 11:30 a.m.

Structure No. Headquarters' Canal — Inspector(s): Dion Broussard (CPRA)
Daryl Clark (USFWS)
Structure Description: Control Structure — Brandon Samson (NRCS) for other inspections
Water Level Inside:N/A Outside: N/A
Type of Inspection: Annual — Weather Conditions: Cloudy skies and cold temperatures

Item	Condition	Physical Damage	Corrosion	Photo #	Observations and Remarks
Steel Bulkhead / Caps	N/A				
Steel Grating	Good				
Gates	Good			3 & 4	
Electrical	Good				
Hardware	Good				
Timber Piles	Good			3	
Caps					
Timber Wales	Good				
Actuators	Good				
Cables	N/A				
Signage /Supports	N/A				
Rip Rap	Good			3 & 4	
Earthen Embankment	N/A				

What are the conditions of the existing levees?
Are there any noticeable breaches?
Settlement of rock plugs and rock weirs?
Position of stoplogs at the time of the inspection?
Are there any signs of vandalism?

MAINTENANCE INSPECTION REPORT CHECK SHEET

Project No. / Name:CS-23 Sabine Refuge Structure Replacement

Inspector(s): Dion Broussard (CPRA)
Daryl Clark (USFWS)
Brandon Samson (NRCS) for other inspections

Structure No.: West Cove Canal

Water Level Inside:N/A Outside: N/A

Structure Description: Control Structure

Weather Conditions: Cloudy skies and cold temperatures

Type of Inspection: Annual

Item	Condition	Physical Damage	Corrosion	Photo #	Observations and Remarks
Steel Bulkhead / Caps	N/A				
Steel Grating	Good				
Gates	Good			5 & 6	
Electrical	Good				
Hardware/Stairs	Good			5	
Fencing	Good				
Timber Piles	Good				
Timber Wales	N/A				
Actuators	Good			5	
Cables	Good				
Signage /Supports	Good				
Rip Rap	Good			5 & 6	
Earthen Embankment	N/A				

What are the conditions of the existing levees?
Are there any noticeable breaches?
Settlement of rock plugs and rock weirs?
Position of stoplogs at the time of the inspection?
Are there any signs of vandalism?

Appendix D
(Excerpts from Operational Plan)

Excerpts from the "Replace Sabine Structures Operation Plan"

V. DESCRIPTION OF WATER MANAGEMENT PLAN

Operation Goals of the New Water Control Structures. The proposed replacement structures were designed to increase management capabilities and provide greater water discharge capability than the existing structures (Table 1). The operational plan for the new structures has been developed to maintain the existing marsh types and provide the following goals:

1) To increase water discharge capacity and reduce adverse impacts from excessive rainfall and storm surges which push excessive saline water into the area,

2) To curtail saltwater intrusion into interior low-salinity marshes, and

3) To provide greater cross-sectional area for improved estuarine-dependent fish and shellfish access.

The water management plan for each new structure provides for unimpeded water exchange through a cross-sectional area approximately equivalent to that of the existing structure when fully open. Additional water exchange would be allowed, upon the refuge manager's discretion, for the purpose of discharging excess water, introducing fresh water or water of lower salinity, improving ingress and egress of estuarine-dependent fishes and shellfishes, and discharging anoxic water or to remediate other water quality problems.

The operational plan would also allow the new structures to restrict or halt saltwater inflow to protect intermediate marshes from saltwater damage. The intermediate marsh areas occur primarily within the northwestern and southwestern portions of the project area. Intermediate marshes also occur beyond the western project area boundary along Central Canal. Saltwater intrusion into these areas occurs primarily through Central Canal and through the open water area of the northeastern project area adjacent to Sabine NWR Management Unit 1. Two data collection platforms (Stations' BC and BN) have been established along each of these two saltwater routes to monitor the rate and extent of saltwater penetration into project area intermediate marshes (Figure 2).

Because Station BC is located at a site from which saltwater readily enters intermediate marshes to the south, west, and north, it was determined to be a critical salinity monitoring station. Station BN is in an intermediate marsh area, hence it was also determined to be a critical monitoring station.

Station BN and Station 5R Structure Operation Criteria. Salinity data compiled for stations BN and BC reveal that the period 1984 through 1988 was the most saline on record, and the period 1989 through 1993 was the freshest on record. Mean monthly salinities were plotted for both the 1984-1988 and 1989-1993 periods (Figures 3 and 4). To maintain existing intermediate marsh vegetation, it was assumed that maintenance of an appropriate salinity range would be most critical during the beginning and middle portions of the growing season from March through August. The new structures will be operated to maintain growing season salinities at Station BN between that of the 1984-88 and 1989-93 extremes. Hence, 3 parts per thousand (ppt) was established as the Station BN structure closure criteria (Water Control Structure Operational Plan-Attachment 1). Given that high salinity events occur with greater frequency from September through February, the Station BN closure criterion during this period was established at 5 ppt (the lower range of the monthly maximum values).

Saltwater may reach Station BN by either flowing northward up Beach Canal from the West Cove Canal Structure, or it may flow across open water areas in Unit 1 from the Hog Island Gully Structure. Station 5R was established to monitor the influence of saltwater inflows through the Hog Island Gully Structure on Unit 1 open water areas. Salinity criteria were established for Station 5R to restrict saltwater inflows and reduce the potential that east or southeast winds will push high salinity waters across Unit 1 and exceed closure criteria at Station BN. To establish those inflow restriction criteria at Station 5R, four years of simultaneous readings from Stations BN and 5R were compared. Those data revealed that Station 5R salinities averaged 2.4 ppt higher than those at Station BN. For this reason, inflow restriction salinity criteria at Station 5R were established 2 ppt higher than closure criteria at Station BN.

Saltwater inflow restrictions to protect intermediate marshes in the vicinity of Station BN would also be triggered when salinities at Station BN reached levels 1 ppt less than the closure criteria. When salinities at Station BN reach the inflow restriction criteria, refuge personnel will utilize other salinity data, precipitation, wind direction,

wind speed, east Unit 3 spillway operations and other factors to determine whether the saltwater came from the Hog Island Gully Structure or from the West Cove Canal Structure. Only those refuge structure(s) determined to have caused the high salinity conditions will be closed or restricted. Should refuge personnel determine that the saltwater came from both the West Cove and Hog Island Gully Structures, then both structures will be closed. Additional safeguards against saltwater intrusion from the south via Beach Canal will be provided by the criteria at monitoring Stations C and BC.

Station BC and Station C Structure Operation Criteria. Station BC is located in a deteriorated brackish marsh area (Figure 5). This station will monitor salinity inflows primarily from the West Cove Canal and Headquarters's Canal structures prior to the dispersal of those flows to the south, west, or north. Because of the salinity fluctuations at Station BC, mean salinities during 1984-88 and 1989-93 (Figure 4) were used less than the unaveraged data presented in Tables 2 and 3. Based upon that data, gate closure criteria were chosen between the extremely high salinity conditions of 1984-88 and the low salinity conditions of 1989-93. The March-August salinity criteria for gate closure was determined to be 6 ppt, and the September-March salinity closure criteria was determined to be 10 ppt (Water Control Structure Operational Plan-Attachment 1).

To protect intermediate marshes located to the north, west, and south, of Station BC, and to reduce the extent of complete gate closures triggered by those high salinities, Station C was established to monitor saltwater inflows heading for Station BC. Salinity values at Station C, which trigger inflow restrictions through the West Cove Canal and Headquarters Canal Structures, were determined by readings from July 1990 through August 1998. During this period, Station C salinities averaged 2.1 ppt higher than those at Station BC. Therefore, the growing season inflow restriction criteria at Station C were set 2 ppt higher than the Station BC structure closure criteria. Given that saltwater inflows here are contained within canals, the non-growing season inflow restriction criteria at Station C was set at the same value as Station BC closure criteria to ensure that intermediate marshes are not impacted. Hence Station C inflow restriction criteria are 8 ppt during the growing season and 10 ppt during the non-growing season (Water Control Structure Operational Plan-Attachment 1). Additionally, should Station BC salinities reach or exceed 4 ppt during the growing season, or 8 ppt during the non-growing season (that is 80 percent of closure criteria values), then the Headquarters' Canal and West Cove Canal Structures may be operated to restrict saltwater inflows.

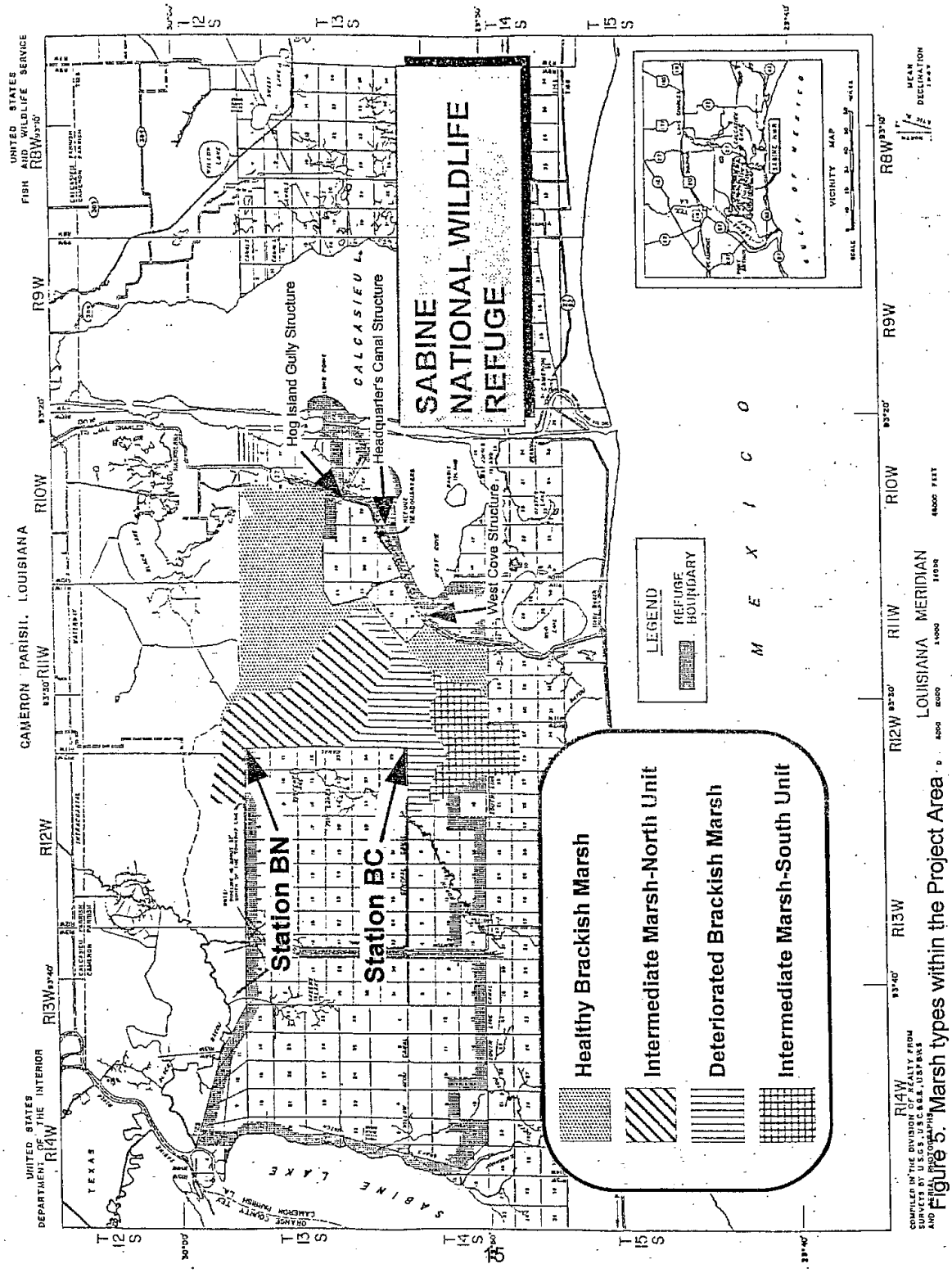


Figure 3. Marsh types within the Project Area

Station BS Structure Operation Criteria. Salinity monitoring conducted at Station BS (located at the intersection of Beach Canal and Southline Canal) will ensure that saltwater does not adversely impact intermediate marshes south of the project area. Saltwater reaching this station would likely come from the West Cove Canal Structure via Central Canal. However, it might also come via the East Mud Lake area through South Line Canal, or from high tides overtopping the beach rim. Station BS salinity criteria for restricting saltwater inflow and closing structures will be the same as those at Station BC (6‰-growing season; 10‰-non-growing season). When those criteria are met, refuge personnel will evaluate other salinity data, tides, precipitation, wind speed and direction, plus other factors to determine the source of saltwater. If refuge personnel determine that salinities came from Central Canal, then the Headquarters Canal and West Cove Canal structures will be closed or restricted as appropriate. If the saltwater at Station BS is determined to have come over the beach rim, then, pending refuge manager discretion and conditions elsewhere, refuge structures will likely be left open to discharge that water.

Inflow Restriction Criteria Summary and Structure Operations. When the salinities reach or exceed any of the salinity criteria specified below (see Table 4), the refuge manager will determine the source of high salinity water causing the criteria to be reached or exceeded. Only those refuge structure(s) determined to be admitting the saltwater will then be operated to restrict future saltwater inflows. During inflow restriction operations and all periods when water level safety provisions are not in affect, the refuge manager may use his discretion to configure the flapgates and/or other gates to discharge water as desired. When the salinity levels at the station(s) prompting inflow restrictions fall below the inflow restriction criteria, then normal water exchange will be resumed.

Restricted inflow through the Hog Island Gully Structure will be achieved by allowing inflow through only one, fully open, 3-foot-wide gate (22% of normal cross-section). Restricted inflow through the West Cove Canal Structure will be achieved by completely closing the Headquarters' Canal structure to all inflow and by restricting inflow at the West Cove Canal Structure to only one, fully open, 3-foot-wide gate (20% of normal combined cross-section), or, by completely closing the West Cove Canal Structure and allowing exchange through one Headquarters Canal culvert opened 75 percent.

Table 4. Salinity criteria (ppt) for restricting saltwater inflows

		Monitoring Station				
Season	Months	C	BC	BS	5R	BN
Growing	Mar. - Aug.	8	4	4	5	2
Non-growing	Sep. - Feb.	10	8	8	7	4

Gate Closure Criteria Summary and Structure Operations. When the salinities reach or exceed any of the salinity criteria specified below (see Table 5), the refuge manager will determine the source of that saltwater. Only those refuge structure(s) determined to be admitting the saltwater will then be operated to preclude further saltwater inflow. During periods of gate closures and all periods when water level safety provisions are not in affect, the refuge manager may use his discretion to configure the flapgates and/or other gates to discharge water as desired. When the salinity levels at the station(s) prompting gate closures fall below the closure criteria, then normal or restricted inflow operations will be resumed depending on area salinities.

Table 5. Salinity criteria (ppt) for halting all saltwater inflows

		Monitoring Station				
Season	Months	C	BC	BS	5R	BN
Growing	Mar. - Aug.	-	6	6	-	3
Non-growing	Sep. - Feb.	-	10	10	-	5

Special Gate Openings for Marine Organism Ingress and Egress. When salinity criteria (Table 5) provide for complete elimination of inflows, short-term special gate openings will be conducted to provide ingress and egress as follows:

a) ***March 1st through April 15th***. During this critical brown shrimp ingress period, one 3-foot-wide gate will be completely open, during incoming tides, at night

only, for 3 to 6 hours per day, for 3 consecutive nights each week. Those openings should be targeted for post-dusk or pre-dawn periods, to the degree possible.

b) ***May 15th through June 14th***. During this critical brown shrimp egress period, a minimum of one 3-foot-wide gate should be fully opened during outgoing tides, for a 6-8 hour period, once a week. Those openings should be conducted during periods of darkness to the greatest degree possible.

c) ***June 15th through July 31st***. During this critical white shrimp ingress period, one 3-foot-wide gate will be completely open, during incoming tides, at night only, for 3 to 6 hours per day, for 3 consecutive nights each week. Those openings should be targeted for post-dusk or pre-dawn periods, to the degree possible.

d) ***Opening of white shrimp season through Nov. 31st.*** During this white shrimp egress period, special openings should be conducted during outgoing tides, in conjunction with the opening of white shrimp season. Following that, openings should be conducted 3 to 4 times a month, and/or associated with the passage of cold fronts.

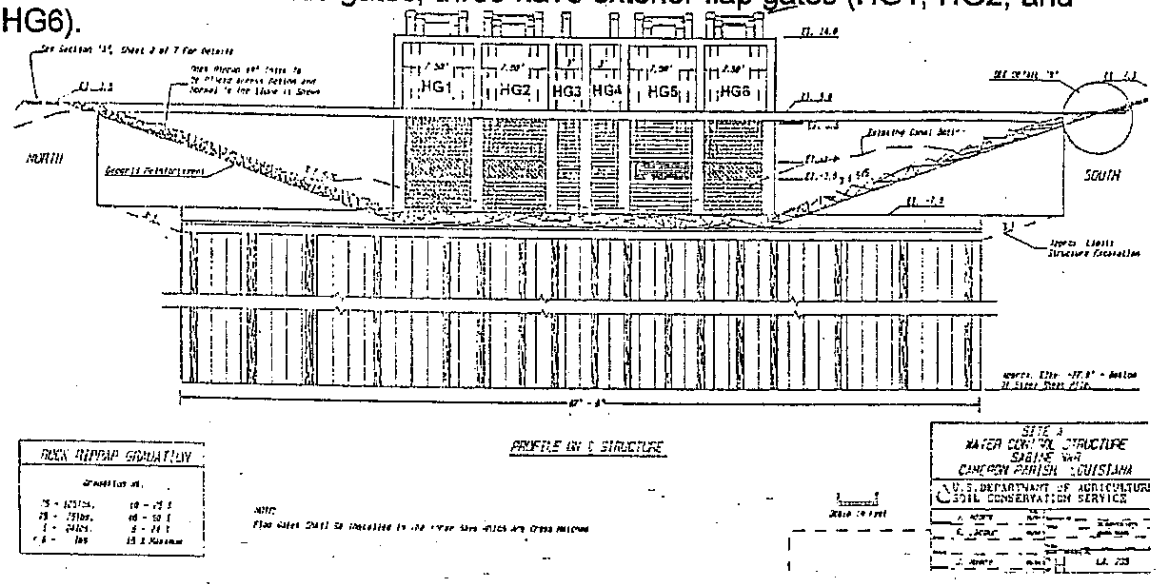
e) ***September 1st through September 30th***. During this ingress period for red drum, one 3-foot-wide gate will be completely open, during incoming tides, at night only, for 3 to 6 hours per day, for 3 consecutive nights each week. Those openings should be targeted for post-dusk or pre-dawn periods, to the degree possible.

Structure Operations During Periods of High Water Levels. Marsh elevation will be determined and staff gauges installed to provide information on project area water levels (Figure 6). Water level data from those staff gauges and from project area DCP's will be used to trigger special gate openings to facilitate discharge of excess water. Generally, if interior marsh water levels exceed the marsh surface [*defined as the surface of the marsh sediment at the base of marsh vegetation at the juncture of the marsh plant shoots and marsh floor (or mud/detritus surface)*] by two inches for two weeks, then sluice gates on each flapgated bay will be raised to discharge excess water. Under such conditions, all inflow through non-flapgated bays will be halted until project area water levels are dropping and at or below two inches above marsh level. At that time, normal exchange will be resumed. During periods of normal water levels, the refuge manager, may allow discharge through flapgated bays according to his discretion.

Structure Operations During Tropical Storms. Prior to a storm's approach, flapgated bays may be readied in advance for later discharge of excess water by raising the interior sluice gates of those bays equipped with flapgates. Prior to a storm's approach, refuge personnel may restrict or close non flapgated bays to reduce exposure of interior marshes to saltwater tidal surges. Following a storm, normal or restricted water exchange operations shall be resumed on non-flapgated bays in accordance with the established salinity and water level provisions and criteria.

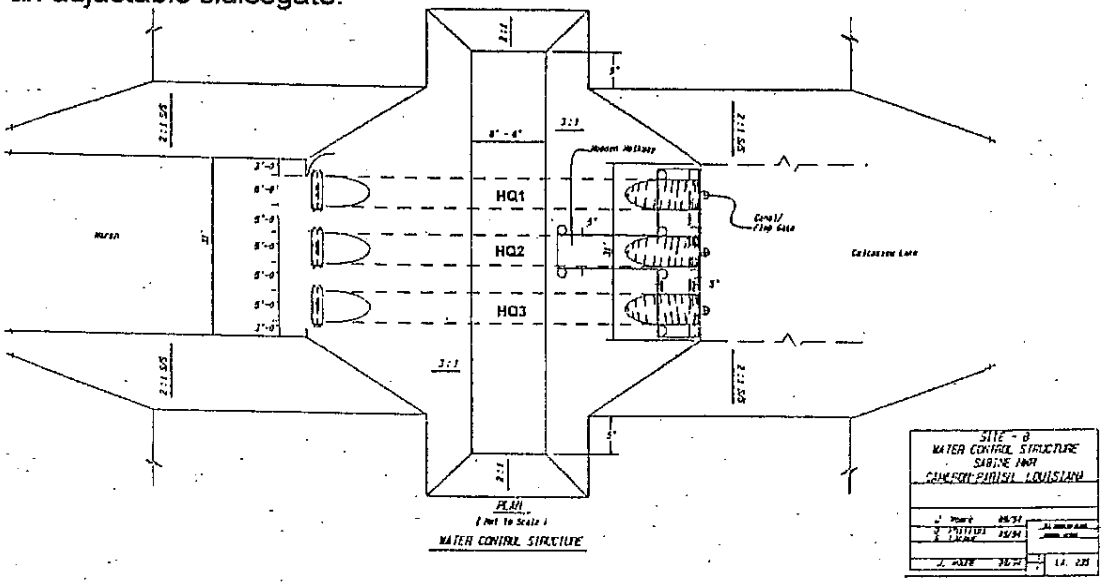
Structure A - Hog Island Gully Canal (see below)

This structure has four 7.5 foot wide gates (HG1, HG2, HG5, and HG6) and two 3.0 foot wide gates (HG3 and HG4) [306 ft^2 total area]. Each gate is 8 foot deep, assuming that water level is at marsh elevation (1.0' NGVD). Each gate is equipped with stop logs on slide gates that may be used to preclude all water flow. Of the four 7.5 foot wide gates, three have exterior flap gates (HG1, HG2, and HG6).



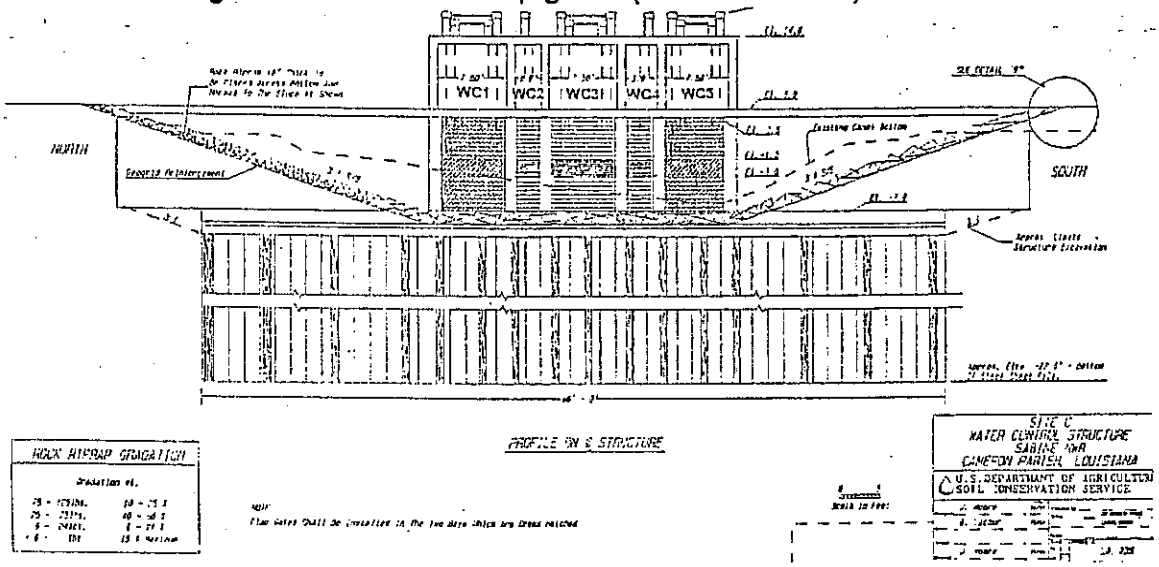
Structure B - Headquarters' Canal (see below)

This structure has three 5 foot diameter culverts (HQ1, HQ2, and HQ3) [59ft^2 total area]. The top of each culvert is at marsh level (1.0' NGVD). Each gate is equipped with an exterior flap gate that may be raised and locked closed to serve as an adjustable sluicegate.



Structure C - West Cove Canal (see below)

This structure has three 7.5 foot wide gates (WC1, WC3, and WC5) and two 3.0 foot wide gates (WC2 and WC4) [242 ft^2 total area]. Each gate is 8 foot deep, assuming that water level is at marsh elevation (1.0' NGVD). Each is equipped with stop logs in slide gates that may be used to preclude all water flow. Two of the four 7.5 foot wide gates have exterior flap gates (WC1 and WC5).



Normal Operation: Water exchange will be provided through open bays having approximately the same cross-sectional area as that provided by the old structures' fully open gates [182 ft^2 total area]. The slide/sluice gates of the flapgated bays may be adjusted by the refuge manager at his discretion, except for the middle Headquarters' Canal Structure culvert (HQ2) which will remain 50 percent open. All flapgates will remain down in the operating position, except for HQ2 in which the flapgate will be locked closed to serve as the sluice gate.

Hog Island Gully Canal - Structure A. Normal management of this structure would provide a cross-sectional area of 112 ft^2 compared with 93.5 ft^2 of gated opening in the old structure.

HG1	HG1	HG2	HG2	HG3	HG3	HG4	HG4	HG5	HG5	HG6	HG6
Stop Logs	Flap Gate	Stop Logs	Flap Gate	Stop Logs	Flap Gate	Stop Logs	Flap Gate	Stop Logs	Flap Gate	Stop Logs	Flap Gate
MD	Down	MD	Down	-7'	None	-7'	None	-7'	None	MD	Down

Headquarters' Canal - Structure B. Normal management provides a cross-sectional area of approximately 10 ft^2 compared with 0 to 12.6 ft^2 of gated opening maintained through operation of the old structure.

HQ1 Sluice	HQ2 Sluice	HQ3 Sluice
Sluice Open	Sluice ½ Open	Sluice Open

West Cove Canal - Structure C. Normal management would provide a cross-sectional area of 60 ft^2 compared 59.5 ft^2 of gated opening in the old structure.

WC1 Stop Logs	WC1 Flap Gate	WC2 Stop Logs	WC2 Flap Gate	WC3 Stop Logs	WC3 Flap Gate	WC4 Stop Logs	WC4 Flap Gate	WC5 Stop Logs	WC5 Flap Gate
MD	Down	+2'	None	-7'	None	+2'	None	MD	Down

MD=Manager's Discretion

Deviations from normal operation will be short-term and conducted for the reasons identified below.

Increased Exchange Operation:
Additional gates may be temporarily opened to the degree necessary as determined by the refuge manager for any of the following reasons.

1) To discharge excess water
2) To facilitate inflow of freshwater, or water of lower salinity
3) To enhance ingress and egress of estuarine-dependent fishes and shellfishes
4) To discharge anoxic waters

High Water Provisions: When water levels in interior marshes exceed four inches above average marsh level for four days or more, the discharge capacity of structures A, B, and/or C will be increased with flap gates or by opening stop logs or sluice gates to permit outflows. Normal operation will be restored when high water conditions have receded.

Storm Provisions: Prior to a storm's approach, flapgated bays may be readied in advance for later discharge of excess water by raising and thereby opening the sluice gates of those bays equipped with flapgates. Prior to a storm's approach, refuge personnel may restrict or close non-flapgated bays to reduce exposure of interior marshes to saltwater tidal surges. Following a storm, normal or restricted water exchange operations shall be resumed on non-flapgated bays in accordance with the established salinity and water level provisions and criteria. In an attempt to reduce the exposure of interior marshes to saltwater because of tropical depression tidal surges, the gates will be closed precluding any surges. Following the inundation of high tides and rainfall, the gates will be opened to alleviate interior marsh flooding.